High-Impact Weather Prediction Project (HIWPP)

Project Plan for Public Law 113-2, the FY2013 Disaster Assistance Supplemental

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Project period: 14 February 2014 – 30 September 2016

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Executive Summary

Highly skillful weather forecasts facilitate making correct decisions further in advance of high-impact weather forecast events like Superstorm Sandy; decisions that can save lives and mitigate loss of property. These longer-lead forecasts necessitate the use of global forecast modeling systems and ensembles. Evidence from Sandy and other events has shown that the global predictions generated in the US can be increased in quality, judging from the somewhat greater skill forecasts from other modeling systems such as those produced at the European Centre for Medium-Range Weather Forecasts (ECMWF).

Public Law 113-2, Disaster Relief Appropriations, seeks to address this gap by providing funding to NOAA to accelerate and enhance the development of new and improved global numerical weather prediction models through the High-Impact Weather Prediction Project (HIWPP). In this project, the NOAA Office of Oceanic and Atmospheric Research (OAR) Earth System Research Laboratory (ESRL) will coordinate a broad-based research, development and demonstration effort aimed at advancing our Nation's global numerical weather modeling capabilities along several fronts:

I. The primary goal of this project is the development of a global non-hydrostatic medium-range prediction system capable of explicitly resolving cloud processes that play a role in most high-impact weather forecasts: e.g. simulating processes such as deep convective clouds; tropical cyclones; terrain-forced precipitation. These models also have important applications for subtler, though no less important processes such as feedbacks between clouds, precipitation and the surface energy budget in Polar Regions. This should help NOAA (and its partner agencies) make a quantum leap forward in its global numerical weather prediction capabilities, from low latitudes to high, by the end of the current decade (2020).

Currently there is no operational instance of a global non-hydrostatic model running in the United States, and the envisioned non-hydrostatic extension of the legacy global spectral model (GSM-GFS) model at NCEP has several developmental risks. Indeed, while there are a number of non-hydrostatic models under development, some more advanced than others, they all possess an inherent level of risk. Hence one part of the HIWPP risk reduction strategy is to evaluate and assess a number of dynamical cores, based on objective performance measures and other criteria, such as adaptability to evolving computer architectures. The outcomes from the dynamical core evaluation will provide important information and guidance to NCEP as they consider their evolution into the next generation of high-resolution global numerical weather modeling.

II. Complementing this longer-term goal, it may be possible to make significant improvements to existing hydrostatic systems in the next 1-3 years. This will be achieved in part, by running the hydrostatic models at or near their maximum practical resolution (~10-km); but also through the development of new data assimilation, ensemble prediction, and physical parameterization algorithms appropriate for cloud-permitting resolutions. Initially these will be developed with hydrostatic models in collaboration with NCEP/EMC, but they will be adapted and refined as needed for the non-hydrostatic models. As such the hydrostatic and non-hydrostatic efforts are interwoven. Note that as a part of the aforementioned risk reduction strategy, a non-hydrostatic dynamical core will be identified for continued R&D to incorporate these new assimilation and ensembling techniques, and physical parameterizations, to develop a system that can produce 10-day forecasts at ~ 3-km – 3.5-km global resolution, which is fast enough to meet operational requirements by 2020, and with a forecast skill exceeding that of the updated hydrostatic GFS and other chosen baselines. To achieve these levels of performance, another key aspect of the non-hydrostatic subproject will be to focus on optimizing this new system for a variety of possible future computational architectures, such as traditional CPUs coupled to multi-threaded coprocessors. These lessons learned will be available to other model development groups.

To set one key baseline for measuring the performance of the new non-hydrostatic modeling systems, this project will also coordinate a quasi-real-time demonstration of an ensemble of existing advanced hydrostatic global prediction systems using models from NOAA/NWS/EMC, ESRL/GSD and the US Navy. These experimental forecasts and graphical products, which are expected to have intrinsic value and improved skill, will be made available to the broader weather enterprise and will be carefully verified. The enhanced ensemble predictions from ESRL/GSD and the US Navy will be carefully evaluated to determine whether they add sufficient value to be incorporated into the operational North American Ensemble Forecast System (NAEFS). Pending a successful demonstration of the advanced assimilation, ensemble prediction and parameterization improvements during the real-time demo, the HIWPP project team will coordinate with NCEP/EMC staff with the possibility of implementing them in the NCEP global models in approximately early 2016.

III. Two separate, smaller projects will also be funded through this plan: (i) the incorporation of nested regional Hurricane Weather Research and Forecasting (H-WRF) models into the NCEP Non-hydrostatic Multi-scale Model on B-grid (NMMB) modeling system (with options to test H-WRF in other non-hydrostatic modeling systems), and (ii) an effort to augment the ongoing expansion of the National Multi-Model Ensemble (NMME) capability for seasonal prediction, to help to create through HIWPP a seamless suite of forecast tools that reach further out in time.

IV. A services framework will be developed that is focused on the timely and accurate collection and delivery of gridded global weather data and related earth system information, with advanced visualization capabilities. The starting point will be the NOAA Earth Information System (NEIS) infrastructure prototype which is designed to deliver model data on global to local scales at the request of the user, which include external data users.

HIWPP Goal

The goal of HIWPP is to improve the United States' operational global numerical weather prediction systems.

In the next three years we seek to improve our hydrostatic-scale global modeling systems and demonstrate their skill. In parallel, we will accelerate the development and evaluation of higher-resolution, cloud-resolving (non-hydrostatic) global modeling systems that could make a quantum leap forward in our nation's forecast skill by the end of the current decade.

1.0 Introduction

Hurricane/Post-Tropical Cyclone Sandy has called attention to the need to invest in and invigorate our numerical weather prediction infrastructure for the United States[1,2]. Public Law 113-2, *"Disaster Relief Appropriations"*, seeks to address this gap by providing funding to NOAA to accelerate and enhance the development of new and improved global numerical weather prediction models through the High-Impact Weather Prediction Project (HIWPP).

HIWPP's overarching objectives are to:

- Improve the current generation (hydrostatic) of global numerical weather prediction models (NWP), run them at higher resolutions and for longer forecast periods (medium range and beyond), and generate new ensemble products.
- Accelerate the development of the next generation of (non-hydrostatic; cloud resolving) global NWP models for medium range forecasts.
- Develop and integrate new scale-aware physical parameterizations of key atmospheric processes, and a new approach to data assimilation known as four-dimensional ensemble-variational (4D-En-Var) assimilation into both the hydrostatic and non-hydrostatic models.
- Optimize models to run on state of the art computer systems, namely the massively parallel fine grain (MPFG)/graphical processing unit (GPU)-based computers.
- Create low latency tools built on high-speed networks to collect, access, extract, evaluate and visualize high resolution, gridded global earth information, and make it available to the broader weather community comprised of data user, and solicit their feedback.

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[1] http://www.usatoday.com/story/weather/2012/10/30/sandy-hurricane-models/1668867/w
[2] http://www.usatoday.com/story/weather/2013/10/26/weather-hurricane-superstorm-sandy/3178777/

Some of these goals are relatively low risk and will yield advances in the short-term (1-3 years), whereas others entail a greater research and development effort and will have longer-term benefits (out 5-6 years).

This project plan describes how HIWPP is going to go about achieving these objectives. Using "Hurricane Sandy Supplemental Funding", HIWPP will focus, accelerate and enhance a number of ongoing R&D efforts on these challenges.

1.1 Problem Statement

Skillful medium-range weather forecasts can facilitate making correct weather-related decisions further in advance of high-impact events like Superstorm Sandy, decisions that can save lives and mitigate the loss of property. These longer-lead forecasts necessitate the use of global prediction systems and ensembles. Evidence from Sandy and other events has shown that the global predictions generated in the US can be increased in quality, judging from the somewhat greater skill of forecasts from other modeling systems such as those produced at ECMWF.

For the US to provide world-leading environmental predictions in the future, we will need to make advances with many aspects of the weather prediction process. These include running the forecast model at finer resolution, using improved data assimilation, ensemble, and

Box 1 Impacts of Hurricane Sandy

"Hurricane/Post-Tropical Cyclone Sandy was unique in many ways. Its historically unprecedented track approached New Jersey and New York from the east. Sandy also made an atypical transition to post-tropical status. The storm evolved when a tropical cyclone merged with an intense low pressure system and dramatically increased in size before landfall."

"Sandy made landfall along the southern New Jersey shore on October 29, 2012, causing historic devastation and substantial loss of life. The National Hurricane Center (NHC) Tropical Cyclone Report estimated the death count from Sandy at 147 direct deaths. In the United States, the storm was associated with 72 direct deaths in eight states... The storm also resulted in at least 75 indirect deaths. "

"Damage estimates from Sandy exceed $50 billion, with 24 states impacted by the storm. Sandy was so large that tropical storm force winds extended over an area about 1,000 miles in diameter. Sandy caused water levels to rise along the entire East Coast of the United States from Florida northward to Maine. The highest storm surges and greatest inundation, which reached record levels, occurred in New Jersey, New York, and Connecticut"

Excerpted and paraphrased from the NOAA Hurricane/Post Tropical Cyclone Sandy ***Service Assessment.***

parameterization methods, and incorporating physically appropriate couplings between model state components (atmosphere, ocean, land-surface/hydrosphere, cryosphere, chemical and aerosols).

While the anticipated increases in computational capacity will be of great benefit, we will soon be able to conduct our current-generation forecast models at resolutions for which they were not originally designed. At resolutions of less than 10 km, the "hydrostatic" assumptions built into our current-generation models become increasingly invalid. At these higher resolutions, the thunderstorms no longer occupy a small fraction of a grid cell, where they can be treated statistically with cumulus parameterizations; they can be as large as or larger than the grid cell itself. These thunderstorms, which play an essential role in hurricane dynamics, should then be predicted explicitly, using "non-hydrostatic" forecast models. In doing so, there is an opportunity to more correctly simulate the dynamics of mid-latitude thunderstorms that spawn tornadoes; many extreme rainfall events; processes in complex terrain; the tropical thunderstorms that drive the global circulation patterns and tropical cyclones; and more subtle, though no less important processes such as feedbacks between clouds, precipitation and the surface energy budget in Polar Regions.

As computational capacity increases in the coming decade, NOAA will jump from the current hydrostatic global model to a non-hydrostatic global model (possibly one *shared* for global and regional applications). The NWS National Centers for Environmental Prediction Environmental Modeling Center (NCEP/EMC) is also exploring whether it will be possible to update their global hydrostatic weather prediction model, the Global Forecast System (GFS), to operate with "non-hydrostatic" dynamics and at convection-permitting resolutions. However, this approach is not without risk. It should be noted that the alternative non-hydrostatic global systems, which are currently under development and testing in the United States, also have challenges and implicit risks to be addressed for potential future use. Hence, it is desirable for NOAA to explore and assess other non-hydrostatic dynamical cores as a part of a risk reduction strategy and to provide information and guidance that NCEP/EMC may use in planning and developing the next generation of operational global numerical weather prediction (NWP) models.

There are several global non-hydrostatic global models under development in the US, including the National Center for Atmospheric Research's (NCAR) Model for Prediction Across Scales (MPAS), the NOAA Geophysical Fluid Dynamics Laboratory's (GFDL) Finite-Volume Cubed Sphere (High Resolution Atmospheric Model; HiRAM), NCEP/EMC's Non-hydrostatic Multi-scale Model on B-grid (NMMB), ESRL/GSD's Non-hydrostatic flow-following finite volume Icosahedral Model (NIM), and Navy's NEPTUNE. Several of these use non-traditional (other than latitude-longitude) grid systems. However, none of these models have yet been adapted and optimized for the medium-range weather prediction problem, including coupling with a cycled data assimilation system.

Before making the jump to a non-hydrostatic modeling system, it may be possible to make significant improvements to existing hydrostatic systems, via improved data assimilation, ensemble prediction, and parameterization approaches, as well as by including the use of a dynamical core with a different formulation; specifically, NOAA/ESRL's Flow-following finite volume Icosahedral Model (FIM). In fact driving the current generation of hydrostatic models towards their maximum performance and resolution is one of the major thrusts of this project.

1.2 Overview of Scientific Objectives

The primary goal of this project is to *accelerate the development of a global non-hydrostatic weather prediction system capable of running at ~3-km resolution in an operational forecast environment by late in this decade*. The beginning phase of the project will leverage the existing global non-hydrostatic-scale modeling efforts in the U.S. To achieve this, existing global non-hydrostatic dynamical cores will be evaluated and compared using a variety of criteria. From this mix, through an objective process, a dynamical core will be identified for further development as a risk reduction alternative to the anticipated non-hydrostatic GFS for operational prediction. This dynamical core will then be optimized for a variety of computer architectures, from CPUs to MPFG computing systems (e.g., Graphics Processing Units (GPUs) available from NVIDIA and AMD, and Intel's Many Integrated Core (MIC)). The dynamical core will be integrated with state-of the-art parameterization suite(s) including the GFS physics suite and with the NCEP operational hybrid ensemble-variational assimilation system and ensemble prediction system. Deterministic and ensemble forecasts will be generated from the new prediction system and compared side-by-side with the forecast fields produced by updated hydrostatic models, discussed below.

It should be emphasized that this is not a selection process per se, but limited resources do not permit the additional development and optimization (in the manner described above) of every non-hydrostatic dynamical core in this project. Furthermore this process is envisioned to provide valuable guidance/insight to NCEP and other operational and research centers, which may choose to leverage these efforts, or directly adopt various components, should they prove effective.

While improving predictions 5-10 years hence requires a fundamental shift to a non-hydrostatic modeling system, there are still several advances that can be made to existing systems in the interim. Another component of this project will thus be to advance the development of data assimilation, ensemble prediction, and the parameterizations in the existing hydrostatic models, and to do so in a way that they can also be applied as well to the next-generation non-hydrostatic models.

As a baseline for subsequent non-hydrostatic global model testing and to provide experimental global model guidance with potential to outperform operational guidance, enhanced experimental hydrostatic modeling systems will then be evaluated in quasi-real-time (pending available computer resources), evaluated internally with existing and newly developed verification tools, and disseminated to interested parties for further evaluation. The ensemble guidance will also be evaluated relative to the existing North American Ensemble Forecast System (NAEFS) guidance to determine whether or not it provides enough additional value for either or both models (FIM; Navy Global Environmental Model, NAVGEM) to be included in the operational NAEFS system.

This project will also support the development of a capability for testing and evaluating global numerical weather prediction systems, and ultimately for running mature systems in near real-time. This capability will complement those now present at the operational center (NCEP) by allowing for more extensive testing of new technologies that may be a large departure from the current operational system. It will also allow for more community involvement in the development, testing and evaluation process. Experimental global-scale and regionally-subsetted model data will be made available to a diverse community of users. This system will leverage a prototype NOAA Earth Information System (NEIS) being developed in ESRL/GSD and will provide advanced visualization and analytics in addition to on-demand dissemination of forecast data.

Related and ancillary objectives include the development of a more modern architecture for generating parallel runs of experimental forecasts, including state-of-the-art verification software and the development of an advanced capability to visualize the experimental model guidance. Additionally, a moderate increment of funding will be applied to evaluate and establish the prediction capabilities of high-impact weather extremes out to several months by leveraging and enhancing the existing National Multi-Model Ensemble (NMME) system and data (temporal resolution, new variables, etc.). Finally, the ability to generate high-resolution (~ 3-km grid spacing) multi-nested forecasts with the Hurricane WRF model will be adapted to NCEP/EMC's NMMB regional modeling system.

1.3 Project Structure

In an unprecedented way, the Hurricane Sandy Supplemental funding provides an opportunity to bring together the nation's global weather modeling community, and focus them on a common goal: the development of the world's best medium-range weather forecast model by the end of the decade. To achieve this goal the team came together beginning early in the process, and once the funding levels were identified, the following thought process emerged leading to the project structure, as it exists herein. This process could be characterized thusly:

- At the core, we need to accelerate the development of the next generation of non-hydrostatic, cloud resolving (3-4 km), global models and run them in a test program ("real time research").
- We need to establish a baseline for the next generation of non-hydrostatic models with the best that we can do with the current generation of hydrostatic models: driving the hydrostatic models to their highest practicable resolution (sub-20 km, approaching 10 km).

- We also need to improve the representation of key physical processes (clouds, radiation, etc.) at finer scales; and to implement new and improved data assimilation techniques.
- We need a test program to collect, evaluate and deliver massive amounts of the new forecast data, as well as supporting data (satellite, surface obs, etc.).
- We need a way to display and animate these vast amounts of information and efficiently conduct comparative analyses.
- Because there are many important processes that occur at scales below even 3-4 km, we need to be able to embed even higher resolution models within our global models (nesting models), especially for key phenomena such as hurricanes.
- Finally, we need to begin to develop a seamless suite of forecasts of high impact weather events that extends to periods beyond 16 days (seasonal).

This logical train of thought, led to the work breakdown structure presented in Figure 1. The numbers in each box are cross-referenced to subsections in Section 3 of this plan. The black boxes in Figure 1 represent the project management and oversight of HIWPP. The project itself is comprised of five subprojects (blue boxes: Hydrostatic Global Models, Non-Hydrostatic Global Models, Moving Hurricane Nest, NMME Expansion, and Test Program), each of which in turn, are comprised of one or more tasks (green boxes; there are 19 tasks in all). Figure 2 illustrates the high-level dependencies between the subprojects. Bold orange arrows denote stronger connections between subprojects, whereas the more tenuous linkages are indicated by a white arrow with an orange outline.

Figure 1 Project organization; a high-level work breakdown structure. Numbers inside of the task boxes correspond to section numbers in this plan.

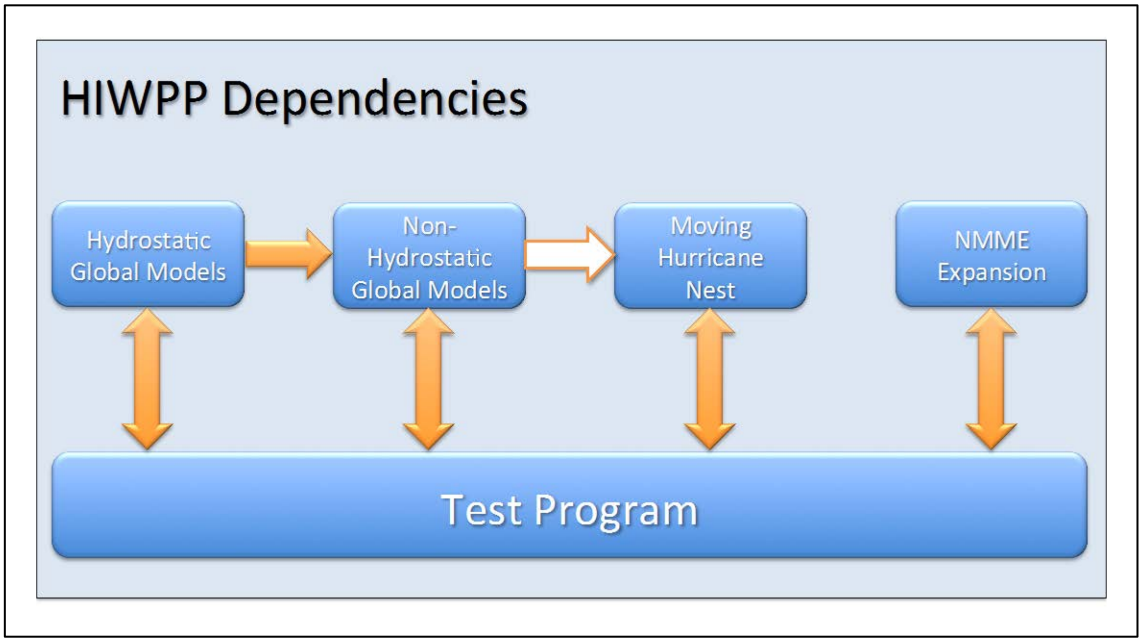

Figure 2 Dependencies between subprojects. The solid orange arrows depict a heavy dependence, whereas the arrow in outline form denotes a weaker dependence.

2.0 Management & Oversight

HIWPP is a large, complex and technically challenging project, with people and facilities spread literally from coast to coast. There are 19 tasks that will be executed nominally by 10 different labs/offices/centers/agencies. Furthermore this is a high-profile project, with special rules and policies associated with the funding, an aggressive timeline, a healthy dose of Congressional interest and even potentially public attention. In short, there is a lot riding on the successful execution of this project beyond the ambitious goal of producing the best possible global forecast models – there is a lot at stake.

Respond to these myriad pressures and successfully conducting this project will require regular and frequent collaboration, strong coordination and proper tracking and reporting; i.e. project management. This section describes the governance, reporting, tracking, and conduct of HIWPP.

2.1 Project Management

Figure 1 describes the management structure of HIWPP, which includes an Executive Oversight Board (EOB), a Project Manager, and a Business Manager/Executive Secretariat. The roles and scope of authority for each of these entities are described in more detail in the EOB Charter (see Appendix C: EOB Charter). In brief:

The EOB provides oversight and guidance to the HIWPP Project Manager in support of project activities. The EOB provides high-level guidance pertaining to policy and direction of the project.

The Project Manager is directly responsible to the EOB for overall project management, as well as project planning, execution, and milestone delivery. The Project Manager will develop the HIWPP project plan, including overall project methodology, schedules, milestones, performance measures, scope and budget and will maintain the baseline plan and changes to that baseline.

The Executive Secretariat/Business Manager works closely with the Project Manager in coordinating delivery of project tracking documentation, updates, and any responses to EOB queries. This person also provides budget management oversight for the project in support of the EOB and Project Manager, and supports the EOB Chair in answering internal/external project data calls or inquiries and assists the Project Manager in the scheduling and conduct of EOB monthly meetings (and other emerging meeting requirements as needed).

2.2 Reporting & Meetings

Nominally the EOB will meet on a monthly basis, and this defines the frequency of routine reporting, which will consist primarily of high-level (quad charts; dashboards) status reports across the project. Thus the project manager will need to meet with the sub-project leads on a monthly basis to inform these updates. As a general rule most project meetings will be partially or wholly virtual (teleconference, etc.). An annual report and summary of accomplishments will be provided to the EOB as well.

The entire HIWPP Team (as represented by all of the Task Leads and other key individuals) will assemble at least once per year, and ideally biannually (preferably in person though this is not mandatory). Working groups and task teams (see below) will meet as defined by the need of each group and the complexity of each sub-project.

2.3 Coordination and Collaboration Across the Project

Each subproject has a Lead who helps to facilitate collaboration and coordination across the subproject, and each task team has a Task Lead. Working groups (WG) will be formed for each of the five subprojects respectively (see Box 2), and will be comprised of the Task Leads, and other individuals as determined by the working group. Each working group will interact as needed, with regular meetings to ensure a well-coordinated effort.

Box 2 HIWPP Working Groups

1. Hydrostatic Global Models WG
   - Lead: S. Benjamin, ESRL
2. Non-Hydrostatic Global Models WG
   - Lead: J. Whitaker, ESRL
3. Moving Hurricane Nest WG
   - Co-Lead: S. Gopalakrishnan, AOML
   - Co-Lead: V. Tallapragada, NCEP
4. NMME Expansion WG
   - Lead: J. Huang, NCEP
5. Test Program WG
   - Lead: B. Strong, ESRL

To foster communication within and across HIWPP and to convey information about the project to external parties, HIWPP has established a presence on the Earth System **Co**mmodity **G**overnance (CoG at http://cog-esgf.esrl.noaa.gov/). The CoG collaboration environment is designed for teams that are developing complex Earth science products, and is especially well suited for this project. The CoG has a number of features, which make it appealing, but at a minimum HIWPP will utilize two features: the Wiki–like capability for sharing information and communication, and metadata for documenting project information (especially model configurations, resolutions, etc.). In this way, CoG will help to foster transparency and awareness. A dedicated space for HIWPP is already in place, and the HIWPP CoG will be available immediately at the beginning the project (see Figure 3; http://cog-esgf.esrl.noaa.gov/). HIWPP team members will be encouraged to maintain basic information about their respective subprojects/tasks, and are encouraged to use the collaborative features. Each model will also need to populate basic metadata via a survey that will be developed by the Project Manager supported by a small, ad hoc committee and the CoG team.

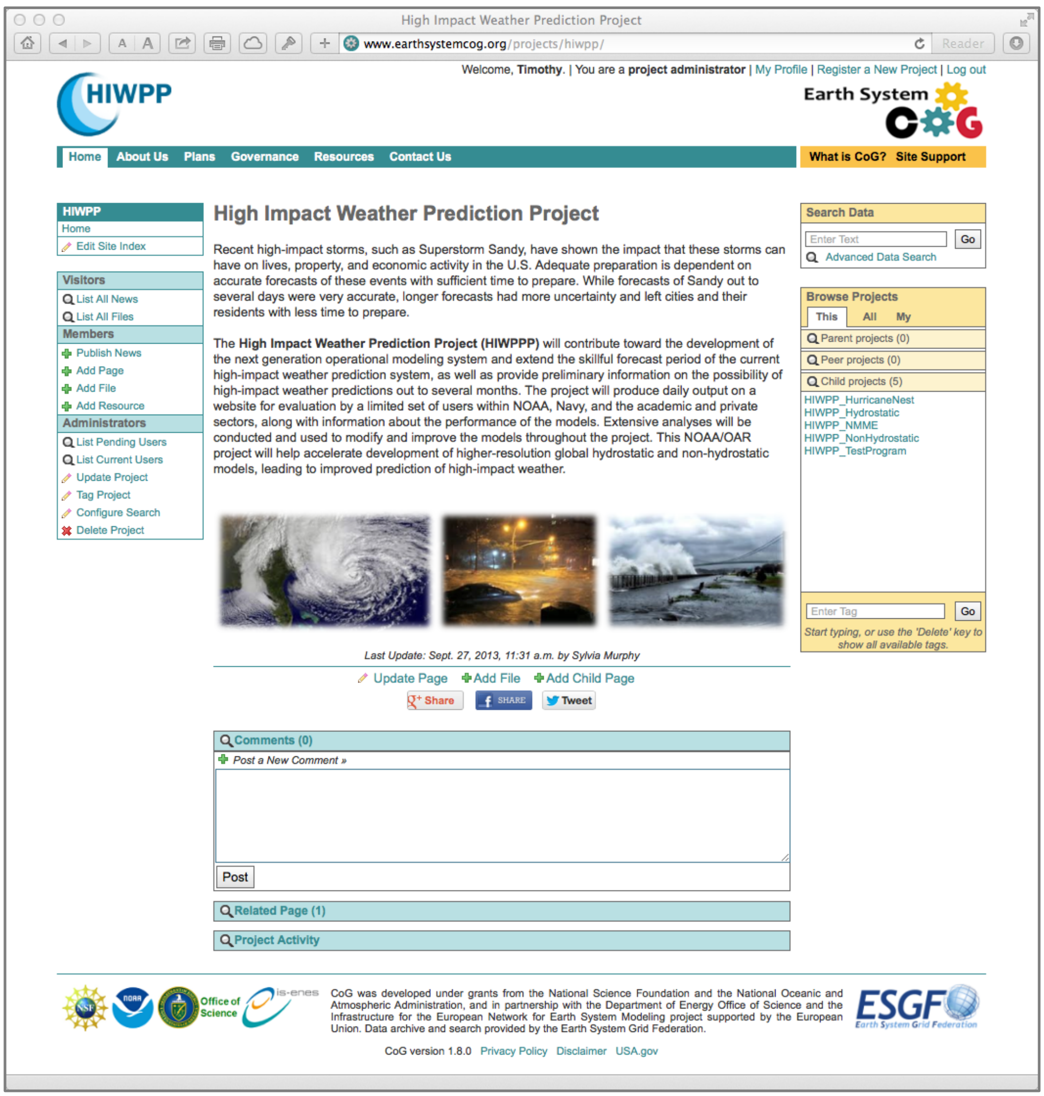

Figure 3 A screen capture of the CoG collaboratory space for the HIWPP project.

Milestones

First Quarter of FY14:

- Working Group Leads "take possession" of each subprojects CoG page and populate.
- Form an ad hoc committee to develop a model metadata survey.

Second Quarter of FY14:

- Modeling teams complete model metadata surveys.

Ongoing (duration of project):

- All – maintain and update these pages.

2.4 Engagement with External Users

An important and valuable part of HIWPP will be engagement with the public, private, and academic sectors in a process the American Meteorological Society has called "real-time research". Engagement with users beyond the project participants enables additional model evaluation from different points of view and feeds back into the model development process, leading to a more robust and effective product development cycle. To this end, HIWPP will develop a process to distribute data and products from this project to external data users.

In order to address any potentially sensitive issues, a Data User Policy will be developed, vetted by NOAA legal and policy advisers, and approved at an appropriate level in OAR and NWS. An initial version of this policy, entitled the "Open Data Initiative" is included as Appendix D.

Milestones

Third Quarter of FY14:

- Ad hoc committee formed to draft a HIWPP data users policy

Fourth Quarter of FY14:

- Legal review of the draft policy
- Review of the draft policy by project task leads

First Quarter of FY15

- Final approval of data use policy received from OAR and NWS leadership

2.5 Risk Mitigation
Risk is an unavoidable and inherent part of any project, especially one as large and complex as HIWPP. HIWPP will actively manage and mitigate risk at several levels and in an ongoing fashion. Coordination within and between Task Teams, Working Groups, and Project Management will be our first line of defense. Working groups will meet regularly. On a monthly basis Project Management will provide written (including a "Dashboard" and a "Quad Chart") and verbal updates to the Executive Oversight Board. In fact this process has already begun (September 2013).

Table 1 Risk mitigation table

Risk/Issue	Mitigation
Risk involved in obtaining desired levels of High Performance Computing (HPC) to support all project activities and objectives	Project activities/objectives will be scaled as necessary to account for HPC availability
Compressed project timeline and associated issues with obligation of funding increase risk of project activity completion	Expedite project plan completion and advanced preparation of funding vehicles to enable timely release/execution of funding
Large complex project with several interdependencies, spread across several offices and agencies	Implement sound project management, oversight and tracking
Risk involved with completion of program activities if extension to funding authority is not extended to FY 2016 for cooperative agreements/contracts	Resolved: OMB approved 10/24/2013.
New: A number of projects will depend on new hires. Finding and hiring technical staff with specialized skills is difficult and potentially time consuming and requires receipt of new project funds.	Coordinate and plan with hiring bodies (contractor/cooperative institute/etc.). Draft and post position descriptions.

For example each task plan section below contains an initial assessment of risks and dependencies. Several common themes have emerged across the tasks, and these have been documented in the initial Quad Charts:

3.0 Task Plans by Sub-Project

Detailed task plans are provided in this section. They are grouped according to the subproject in which they reside.

3.1 Hydrostatic Global Models

Workgroup Lead: Stan Benjamin, ESRL/GSD
Collaborating Groups: CIRA, CIRES, ESRL, NCEP, NRL

Introduction & Overview
The goal of the HIWPP Hydrostatic Global Model Subproject (3.1) is to establish an advanced hydrostatic global model benchmark by which to calibrate performance of the upcoming global non-hydrostatic models developed and tested under section 3.2.

A related goal of section 3.1 is to improve *hydrostatic-scale* medium-range forecast capability via acceleration of development of advanced global models and global ensemble configurations. This will be accomplished, in part, by improvement to components of global models, physical parameterizations and data assimilation. This last area will also be generally transferable to non-hydrostatic global models. All of these goals for hydrostatic global model development in section 3.1 will benefit a larger HIWPP goal: to determine a non-hydrostatic global model that will be the focus of concerted development as a risk-reduction alternative to the non-hydrostatic GFS global spectral model and NMMB under development by NCEP/EMC.

The areas of development under section 3.1 will include data assimilation (DA), ensemble forecasts, and physical parameterizations.

The verification and evaluation to establish this advanced hydrostatic benchmark will include retrospective testing and quasi-real-time testing. The advanced models participating under section 3.1 include the GFS (from NCEP/EMC), NAVGEM (from NRL) and FIM (from OAR/ESRL). Evaluations of these models will include advanced improvements, as each participating lab sees appropriate, in parameterizations, DA, and numerics. These evaluations will include those for deterministic models at highest resolution possible and also for multi-model ensembles.

Planned efforts on the DA and physics and ensemble component for hydrostatic global models will be accomplished primarily by ESRL and EMC and are described under section 3.1.1. The ensemble component under section 3.1 will consider experimental multi-model modifications to the North American Ensemble Forecast System (NAEFS). Variations to the current NAEFS ensemble configuration with GFS/CMC will be evaluated with experimental FIM and NAVGEM ensemble members. In addition, a high-resolution mini-ensemble from three HIWPP deterministic models (FIM and NAVGEM, augmented by the operational forecasts from the high-resolution GFS-SL model at up to 10-15-km resolution) will be evaluated. Efforts on accelerated development of physical parameterizations will focus on scale-aware and stochastic components especially for deep and shallow convection, turbulence/cloud, and aerosol parameterization.

Evaluations will be conducted under section 3.1 for both retrospective tests and quasi-real-time tests. The purposes of the retrospective tests are to benchmark deterministic model skill for participating models to provide expectation for the quasi-real-time performance in both deterministic and ensemble applications. The retrospective tests for these hydrostatic global models, more importantly, will provide guidance for effectiveness of development areas (data assimilation (DA), physics, ensemble design, numerics). It will also provide a final benchmark for comparison of similar retrospective tests with non-hydrostatic global models (run largely at hydrostatic scales). Part of the purpose of quasi-real-time tests is to provide eyeball-forecaster evaluation from users of these experimental advanced hydrostatic models to identify possible problems or notable successes in significant individual weather cases. These quasi-real-time experimental tests will also provide an early look at possible improved skill to HIWPP beta users.

The work plan is as follows
- Retrospective tests
  - Perform once daily (00z 'init time') for 1-year period to provide preliminary relative skill of participating models
  - Forecast duration: 10 days for deterministic and 16 days for ensemble runs
  - Output grids at 0.5 deg. latitude/longitude for deterministic forecasts, 1.0 deg. latitude/longitude for ensemble runs, including all variables currently produced for NAEFS (provided separately)
  - Common test period – to be determined; initial recommendation is for the 1 July 2012 through 30 June 2013 period
- Quasi-real-time tests
  - Run at least 1x/day with a duration of at least 10 days, with a goal of high reliability (95% if possible)
  - Run at highest possible resolution
    - Deterministic: Likely 13km (GFS-SL) for GFS, 10-15km for FIM, ~26km for NAVGEM
    - Ensemble: ~35km for GFS-SL/GEFS, to be determined for FIM and NAVGEM

Verification of these models is described in more detail under section 3.5.3. It will include or exceed current deterministic model verification (e.g., EMC Verification Statistics Data Base (VSDB) verification against grids and observations, ESRL/GSD/AMB interactive verification against observations and grids). Scorecard approaches to combine different scores into an overall measure (e.g., EMC, ECMWF, and UKMO) will be considered. The evaluation of ensemble forecasts will include or exceed that done for ensemble means (e.g., EMC) and ensemble spread measures (e.g., EMC and ESRL).

Again, the outcomes from development under the hydrostatic global model component of HIWPP will be largely applicable to non-hydrostatic models in the future, will improve the HIWPP hydrostatic model baseline, and will accelerate DA/physics/ensemble development and options for NCEP hydrostatic models.

Outputs & Deliverables

Twelve-month retrospective deterministic forecasts at high resolution (up to 10-km – 15-km) out to 10-day duration, and ensemble forecasts (up to ~ 35-km resolution) of 10 members out to 16-day duration will be made. Each subproject 3.1 Team Member will make output from these retrospective test forecasts available to the Task 3.1 hydrostatic global model team and Task 3.5 test program areas as appropriate. Each Task 3.1 team member will ensure that the model output meets current NAEFS/NUOPC protocols. Each team member will produce quasi-real-time products as appropriate and as computational resources allow. Each team member will also coordinate with other Task 3.1 and Task 3.5 working group members in evaluation of multi-model ensemble forecasts.

Quality Criteria

This subproject will be considered a success if at end of FY15 the following criteria are met:

- Improvements have been made to hydrostatic global models in physics, DA, ensemble configurations, and numerics through HIWPP-sponsored development and retrospective testing that have potential benefits for NOAA operational models and future non-hydrostatic global models.
- Benchmarks on model performance have been established via retrospective tests for hydrostatic deterministic and ensemble global models to baseline expected results for subsequent non-hydrostatic global models.
- A quasi-real-time HIWPP forecasting capability for beta users has been made available starting no later than 1 January 2015 to demonstrate next-generation high-resolution global model capability.

Resources

Human Resources:

- Stan Benjamin, ESRL GSD – Sub-Project Lead

Computational Resources:

- Use of existing hardware resources (Zeus and other NOAA computational resources)

Management

The project management team as outlined in the HIWPP Work Breakdown Structure is described as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.1 POC, Benjamin	3.1, 3.2, 3.5 & Project Mgr.	Document
Status Reports	3.1 POC, Benjamin	3.1, 3.3 3.5 & Project Mgr.	Document, Status Report Template
Project Advisory Group	3.1 POC, Benjamin/ 3.2 and 3.5 Test Mgrs., Project Mgr.	ESRL Lab Director	Meeting
Technical Team Meetings	3.1 POC, Benjamin	Technical Team	Project Management Plan

Sponsor Meetings	ESRL Lab Director, Project Manager, 3.1 POC, Test Mgr. & 3.5.3 POC Weygandt	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.1 POC, Benjamin, 3.5.3 POC, Weygandt, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, ESRL Lab Director, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Project Management Guide

Responsibilities of the Hydrostatic Global Models POC/Technical Lead:

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team
- Provide requirements understanding and guidance to the development team
- Coordinate completion by different laboratories of retrospective and quasi-real-time experimental forecasts
- With 3.5.3 POC, coordinate initial implementation of existing verification software and planning for unification of software and addition of new capabilities
- Establish communication plan and schedule with other HIWPP POCs
- Develop tasking, schedule and budget for all aspects of the hydrostatic global model effort in coordination with all groups involved in development
- Coordinate with other HIWPP project areas to leverage meetings, demonstrations and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting and critical develop monitoring and guidance

Milestones

Consolidated milestones across the Hydrostatic Global Models Subproject, include:

Second Quarter of FY14:

- Identify participants, computer resources, and determine model configurations for hydrostatic tests. [ESRL, EMC, Navy]

Third Quarter of FY14:

- Begin retrospective testing and tuning advanced 4D ensemble-variational assimilation system (4D-En-Var) with high-resolution hydrostatic GFS, in collaboration with NCEP [EMC]
- Begin retrospective runs of hydrostatic models [ESRL-FIM, EMC-GFS, Navy-NAVGEM]Initial verification results produced for retrospective runs of

hydrostatic models (retrospective runs continue) [EMC, Navy, ESRL]Coordinate with HIWPP Verification team (section 3.5.3) on evaluation of retrospective deterministic and ensemble forecasts from each participating laboratory [ERL, Navy, EMC]

Fourth Quarter of FY14:

- Expected implementation of improved, higher-resolution GFS [EMC]
- By September, final configuration of a 4D-En-Var system for initializing high-resolution hydrostatic real-time runs. Begin cycling forecasts [ESRL]
- By August, some preliminary retrospective runs over 1-year period of hydrostatic models for deterministic forecasts may be made available to foster development and evaluation
- By September, retrospective runs over 1-year period of hydrostatic deterministic forecasts are completed. [ESRL and NRL]. These will be complemented by retrospective forecasts from the GFS taken from the real-time parallel tests associated with the operational implementation and augmented with retrospective forecasts run by ESRL using the operational GFS code

First Quarter of FY15:

- Retrospective runs over 1-year period of hydrostatic models for ensemble forecasts are complete using whatever configuration deemed optimal for each laboratory [ESRL, NRL, EMC]
    - Coverage will be for the majority of a 1-year period.
    - NCEP will complete test runs with the T1534 GFS for selected periods: 2013 – July-October (retrospective), 2014 – real-time from Feb-July 2014.
    - NCEP will provide T1534 GFS initial files to ESRL, who will, in turn, provide to NRL
    - Both FIM and NAVGEM for these test period will be initialized from the GFS T1534 initial conditions
- Expected implementation of improved, higher-resolution GEFS, and GSI [EMC]
- By October, decision made based on initial retrospective results on hydrostatic model for quasi-real-time ensembles: quasi-real-time forecasts from all HIWPP hydrostatic models will be made available for deterministic and ensemble forecasts through HIWPP. A decision on mini-ensemble from high-resolution models will be made by a working group [ESRL, EMC, Navy members]
- Configuration is finalized for quasi-real-time experimental forecasts from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]

**NB: EMC inputs for these tasks, here and subsequently, are derived from operational forecasts (GFS 13-km or GEFS as appropriate)*

Second Quarter of FY15:

- January: Start of quasi-real-time experimental forecasts from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]
- January: Start of quasi-real-time ensemble forecasts (0-16 days) from hydrostatic models [ESRL, EMC*, Navy]
- Collect and synthesize feedback from beta testers on their impressions of real-time demonstration of hydrostatic models [ESRL]

Third Quarter of FY15:

- Continue quasi-real-time experimental runs from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]
- Continue quasi-real-time experimental ensemble forecasts (0-16 days) from hydrostatic models [ESRL, EMC*, Navy]

Fourth Quarter of FY15:

- Continue quasi-real-time experimental runs from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]
- Continue quasi-real-time experimental ensemble forecasts (0-16 days) from hydrostatic models [ESRL, EMC*, Navy]
- Produce draft report on hydrostatic real-time tests [ESRL, EMC, Navy]

First Quarter of FY16:

- Continue quasi-real-time experimental runs from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]
- Continue quasi-real-time experimental ensemble forecasts (0-16 days) from hydrostatic models [ESRL, EMC*, Navy]

Second Quarter of FY16:

- Complete quasi-real-time experimental runs from hydrostatic models at up to 10-15-km resolution [ESRL, EMC*, Navy]
- Complete quasi-real-time experimental ensemble forecasts (0-16 days) from hydrostatic models [ESRL, EMC*, Navy]
- Submit report on hydrostatic model real-time test results to a peer-reviewed journal [ESRL, EMC, Navy]

Tolerances

Fault	Tolerance	Impact
Initial verification capability	No more than 1 month after scheduled date of June 2014	Initial capability critical for evaluation of early hydrostatic expt. runs
Mid-range verification capability	No more than 2 months after scheduled date of	Mid-range capability critical for evaluation and

	Sept. 2014	decision-making on non-hydrostatic expt. runs
Mature verification capability	Unable to complete in timely manner	Detailed evaluation and testing process for non-hydrostatic models takes longer than expected

Dependencies

The Task 3.1 activity will depend very heavily on Task 3.5 verification activities.

Risks

- Hiring of additional scientist staff
- Insufficient computing resources

3.1.1 Assimilation/Ensembles/Stochastic Physics

Task Leads: Jeff Whitaker (ESRL/PSD) and Tom Hamill (ESRL/PSD)
NB: *This task plan is shared between Hydrostatic Global Models and Non-Hydrostatic Global Model tasks.*

Introduction

ESRL, in collaboration with NCEP/EMC, will develop and test the capability to provide ensemble initial conditions for HIWPP forecasts from an experimental high-resolution 4D ensemble-variational (4D-En-Var) assimilation cycle in advance of its operational implementation at NCEP. ESRL will work closely with NCEP to address the following issues that need to be investigated before operational implementation of 4D-En-Var:

- Reducing or eliminating the amount of additive noise used to inflate variances and modify covariances in the ensemble data assimilation, replacing it with model uncertainty parameterizations in the forecast model. Specifically, we will extend current testing of the ECMWF Stochastically Perturbed Physical Tendency (SPPT), the ECMWF/UKMet Stochastic Kinetic Energy Backscatter (SKEB), and the stochastically perturbed boundary-layer Humidity (SHUM).
- Test methods for reducing the amount of imbalance present in the Ensemble Kalman filter (EnKF) analyses, including incorporating a constraint on increments to the vertically integrated mass-flux divergence.
- Test the impact of tropical cyclone relocation applied to EnKF ensemble members on TC track and intensity forecasts, including a scheme for updating the TC track positions with an EnKF and then relocating to the updated positions. As time permits this may include experimentation with and development of the technique known as “field alignment.”

- With EMC, evaluate 4D-En-Var tests, including the use of the incremental analysis update (IAU) and the digital filter balance constraint.
- With EMC, test the use of incorporating flow-dependent background-error covariances from the hybrid system into the background check of the quality control system. Currently, this capability is in the standalone EnKF but not in the hybrid GSI (which only uses the observation error in the background check).
- Evaluate the impact of reducing sampling error by increasing ensemble size within the 4D-En-Var system, evaluating tradeoffs between ensemble size and ensemble resolution.
- Test methods for introducing perturbations to the land and/or ocean surface state (including the sea surface temperature and soil moisture).
- With EMC, combine the elements of the above work into a preliminary test package as a candidate for operational implementation.
- In collaboration with NCAR (funded under NWS Sandy Supplemental funding) evaluate whether the "EVIL" ensemble-variational algorithm designed by Tom Auligne provides improvements to the basic 4D-En-Var approach.

The methods used to represent model and land/sea surface uncertainty in the data assimilation cycle will also be tested in medium-range forecast ensembles and will be compared against the current operational Stochastic Total Tendency Perturbations (STTP). Their impact will be measured using existing NCEP ensemble verification tools with additions that emphasize sensible weather elements (such as near surface winds, temperature and precipitation). These will be further refined and developed under the verification component of the HIWPP plan.

The non-hydrostatic portion of this task will continue the work begun with the hydrostatic systems, and will focus on two primary tasks:

- Integrating selected non-hydrostatic dynamical cores with the 4D-En-Var data assimilation system, and testing the resulting non-hydrostatic prediction system in cycled data-assimilation mode. Part of this task will involve synthesis and inter-comparison of non-hydrostatic dynamical core (dycore) test results prior to selection of a dycore on which to focus subsequent OAR efforts for DA and optimization.
- Developing and testing stochastic representations of model uncertainty appropriate for non-hydrostatic models running at cloud-permitting resolutions. This work will be shared with the 'Parameterizations' task and will focus on the development of stochastic microphysics.

The change from a hydrostatic to a non-hydrostatic modeling system will almost inevitably reveal issues with the design of the non-hydrostatic dynamical core and how it interacts with the parameterizations. Accordingly, the performance of the ensemble prediction, the data assimilation, and the stochastic parameterization components will be evaluated with the non-hydrostatic dynamical core, and necessary adjustments to each will be made to improve forecast performance.

Outputs & Deliverables

We will deliver ensemble and deterministic initial conditions for the HIWPP hydrostatic model participants in near real time. In addition, the results from retrospective tests run with the operational GFS will be analyzed to document the impact of the individual components of the experimental system listed in the introduction section. The results of this analysis will be used to develop a set of recommendations to EMC for configuration of a test package for pre-implementation testing at NCEP (both the global data assimilation system and the global ensemble forecast system). Data assimilation interfaces for selected non-hydrostatic dynamical cores will be developed for the GSI 4D-En-Var system, and results of retrospective tests will be analyzed and compared to those obtained with the NCEP non-hydrostatic systems (non-hydrostatic GFS and/or global NMMB)

Quality Criteria

The evaluation of the experimental assimilation and forecast system will be done using established verification metrics used at NCEP/EMC, with some additions as described in the previous section. The operational global system will serve as a baseline to measure success. Success will be achieved if the experimental system leads to an operational implementation that demonstrably improves forecast skill. Scientific advancements will be documented in peer reviewed journal articles.

Management

Co-leaders Jeff Whitaker and Tom Hamill will manage this component of HIWPP, reporting to hydrostatic task leader Stan Benjamin program manager Tim Schneider. We will have a strong connection to the Parameterization task (through a shared post-doc developing stochastic microphysics. The development and testing of the 4D-En-Var system will be part of a close collaboration with NCEP/EMC personnel, especially Daryl Kleist and John Derber. Coordination with NCEP/EMC and the HIWPP parameterization tasks will take place in bi-weekly conference calls and face-to-face meetings where appropriate.

Milestones

Second Quarter of FY14:

- Parameters for stochastic physics (stochastic kinetic energy backscatter, stochastically perturbed physics tendencies, and perturbed boundary-layer humidity) tuned for data assimilation and medium-range EPS, using T574L64 semi-Lagrangian GFS ensemble
- Finish testing EnKF TC relocation scheme

Third Quarter of FY14:

- Implement and test incremental analysis update (IAU) within 4D-En-Var system using GFS model
- Implement and test balance constraint for EnKF analysis using GFS model

Fourth Quarter of FY14:
- Initial configuration of quasi-real-time 4D-En-Var analysis system completed

First – Fourth Quarter of FY15:
- Test methods for perturbing land surface and sea surface state within ensemble system

Second – Fourth Quarter of FY15:
- Evaluate the impact of increasing ensemble size in 4D-En-Var system from 80 to 320 members

Second Quarter of FY15:
- Use results of 4D-En-Var testing to recommend a preliminary test package to NCEP/EMC as a candidate for operational implementation.

First Quarter of FY16:
- Interface to 4D-En-Var GSI system completed for selected non-hydrostatic dynamical cores. The dynamical core selection will be based on the extensive testing of the non-hydrostatic dycores in FY14 and FY15 with input from NCEP and the participating non-hydrostatic modeling teams
- Port stochastic microphysics scheme to dycores selected for data assimilation testing and integration

Second – Fourth Quarter of FY16:
- Test the impact of stochastic microphysics scheme within cycled non-hydrostatic data assimilation and forecast system. The impact of the stochastic microphysics on medium range ensembles will also be evaluated, and compared to existing schemes (implemented in the GFS system in FY14 as part of this task)

First – Fourth Quarter of FY16:
- Evaluation of selected non-hydrostatic model(s) within cycled 4D-En-Var system. The baseline for the evaluation will be the non-hydrostatic GFS and/or NMMB model cycled in the same data assimilation system.

Tolerances
NCEP expects a major implementation of the GFS model and assimilation system in Q3FY14 and Q1FY16. Following their procedure, typically 6-9 months prior to this, decisions are made about what components should be included in the operational implementation, the code is frozen, and parallel testing ensues. Accordingly, stochastic physics testing and tuning should be done before Q2FY14 in order for a preliminary implementation of stochastic physics to make it into the FY14 upgrade.

Similarly, a preliminary test package for 4D-En-Var needs to be ready by Q2FY15 for the Q1FY16 implementation.

In order to leave sufficient time for data assimilation integration and testing, a decision on which non-hydrostatic dynamical cores to focus on needs to be made by Q1FY16.

Dependencies
4D-En-Var development and testing will be a result of close collaboration with personnel at NCEP/EMC, and therefore will depend on NCEP/EMC continuing to make this effort a high priority.

The stochastic microphysics work in this task is dependent on the Parameterization task, since the post-doc to develop the scheme is largely funded by that task.

All of the work in this task is dependent on the procurement of adequate computer resources by HIWPP.

Risks
If adequate computer resources are not dedicated to this project, many of the milestones will not be met. If qualified applicants are not found for the data-assimilation and stochastic physics post-docs, development and testing of the 4D-En-Var system and the stochastic microphysics schemes will be delayed.

Budget
Detailed budgets provided under separate cover.

3.1.2 Parameterization Development

Task Leads: Georg Grell (ESRL/GSD) & Tom Hamill (ESRL/PSD)
NB: *This task plan is shared between Hydrostatic Global Models and Non-Hydrostatic Global Model tasks.*

Introduction
This component of the HIWPP project will improve the GFS parameterization suite, developing and testing enhancements in the GFS and FIM models (code will also be available to NRL for Navy NAVGEM hydrostatic model). The parameterizations will be "scale-aware," able to work appropriately with minimal tuning for models with grid spacing from 30 km to 3 km and beyond. They may also include some stochastic elements to increase the spread when applied in ensemble prediction systems.

Pending a successful demonstration and acceptance by NCEP/EMC and their users, some of these improvements may be incorporated into the operational GFS and GEFS systems. It is presumed that these enhanced parameterizations will also be used in the parameterization suite for the non-hydrostatic modeling system to be developed elsewhere under this plan.

This work plan has components that span the hydrostatic and non-hydrostatic model development efforts. The hydrostatic component intends to contribute an operational implementation in the operational hydrostatic models by FY2016, while the component is envisaged to be tested with both hydrostatic and non-hydrostatic models but to have greater applicability to the latter, and any operational implementation will be post 2016.

The proposed work will have two components:

(1) **Unified representation of turbulence and clouds**:
This HIWPP task will accelerate one component of the parameterization development in the Krueger et al. Climate Process Team, which will not be funded until Nov 2014, the development of a unified representation of turbulence and clouds. This parameterization, pending a successful demonstration, would replace the existing turbulence, boundary layer, and cloud macrophysical schemes at marginally increased cost. The key is a simplified representation of higher-order turbulence with assumed probability distributions for the subgrid-scale variability in vertical velocity, temperature, and humidity. Because the evolution of some distributions is explicitly tied to spatial scale the scheme is "scale-aware" i.e. it performs well across a range of mesh sizes including models with irregular spatial discretization. This makes this scheme appealing not only to existing hydrostatic models like the GFS, but potentially well suited to the higher-resolution non-hydrostatic modeling system to be developed elsewhere in this project. The explicit description of variability, especially in clouds, means that non-linear processes such as radiation and microphysics can be treated more exactly, removing the need for some model tuning. The scheme is well tested in other high-resolution global models. NCEP/EMC and OAR/CPO/MAPP support this effort, but MAPP budget constraints mean that funding cannot begin until Nov 2014, which is likely too late to influence models intended for operational use in 2016.

(2) Scale- and aerosol-aware stochastic convective parameterization:
These two additional areas of physics parameterization are also important for HIWPP. With operational global models expected to run at hydrostatic scales through late in this decade, but with proposed stretched grids from 10s of km to single km scales in the near future and on non-hydrostatic scales, some initial research is underway for scale-aware stochastic convective parameterizations (e.g., Grell and Freitas 2013). The key design is to reduce the role of the sub-grid-scale parameterization as grid-length decreases, a capability now available in the latest version of the Grell-Freitas (GF) scheme. This work will be accelerated and tested in the FIM and GFS models through incorporation into the GFS physics suite and will be available for other HIWPP global models. The Grell-Freitas scheme also includes the capability to interact with aerosols through conversion of cloud water to rain and evaporation of raindrops. This is implemented through simple dependence on Aerosol Optical Depth (AOD), which may come from a coupled modeling system such as GFS-GOCART, or it may simply be provided in the initial analysis from

Satellite data. This work will also be accelerated and tested in GFS and FIM, similar to that for the scale-aware capability of the Grell-Freitas scheme.

Outputs & Deliverables

This task will deliver an improved parameterization that can be incorporated into the GFS physics suite that will replace the existing turbulence, boundary layer, and cloud macrophysical schemes at marginally increased cost. Additionally, we will deliver comparative test results that demonstrate the performance of the GFS forecasts with the existing parameterizations and the proposed new unified parameterization. These will be tested with the GFS model otherwise in the anticipated configuration for the early FY 2016 implementation. We will produce a journal article documenting these tests. Our intent is to produce and generate this unified parameterization quickly enough that NCEP/EMC will have the evidence for whether or not to include this in the GFS upgrade scheduled for early FY 2016.

This task will also deliver an advanced scale- and aerosol-aware convective parameterization that has been tested and evaluated in several hydrostatic and non-hydrostatic modeling systems, including the FIM when used with other GFS physics components. The performance will be documented in a peer-reviewed article. This parameterization could be ready for implementation in early FY2016, or components could be moved to the currently used convective parameterization in the GFS.

Quality Criteria

The comparative quality of the numerical weather forecast guidance with and without the parameterizations to be developed here will be documented in peer-reviewed articles. This work will be developed to the point of operational readiness, working hand-in-hand with NCEP throughout this process, providing early information on performance, adapting the parameterizations as needed to be computationally efficient on their systems, and following their software development and documentation standards. At that point further operational decisions and development will be carried forward by NCEP.

Management

Co-leaders Georg Grell and Tom Hamill will manage this component of HIWPP, reporting to hydrostatic task leader Stan Benjamin and non-hydrostatic task leader Jeff Whitaker, as well as to Project Manager Tim Schneider. Robert Pincus of CIRES will act as the scientific lead for the ESRL/PSD components and will interact the most with the personnel working on the unified representation of turbulence and clouds. Pincus also will be largely in charge of developmental decisions. We also envision a very close collaboration with NCEP/EMC personnel, especially those involved with the parameterization development there, e.g., John Derber, Moorthi, and Hua-Lu Pan.

Milestones

(1) Unified representation of turbulence and clouds: It is expected that it will take about a year to deliver a version of the GFS physical parameterization suite in which the higher-order closure scheme has been implemented to replace the turbulence, boundary layer, and cloud macrophysics schemes:

Fourth Quarter of FY14

- Hire postdoctoral associate at NCEP
- Begin adapting new physics modules to NCEP global model

Second Quarter FY 15

- Implement portions of new physics modules in NCEP global model in diagnostic (real-only) mode
- Test and evaluate new physics modules at low resolution

Third Quarter FY15

- Complete implementation of new physics modules in NCEP global model in diagnostic (read-only) mode
- Test and evaluate new physics modules at low resolution

Fourth Quarter FY15

- Test and evaluate NCEP global model interacting with new physics modules at low resolution
- Tune physics as necessary

First Quarter FY16

- Test and evaluate NCEP global model interacting with new physics modules at medium ("climate") resolution
- Tune physics as necessary

Third quarter FY16

- Test and evaluate NCEP global model interacting with new physics modules at full resolution
- Test in forecast-assimilation cycles

Beginning in FY15 the bulk of this effort will be funded separately as a Climate Processes Team by the NOAA Climate Program Office. Results from this ongoing Climate Process Team effort, will be leveraged by HIWPP (and vice versa) and coordinated through Robert Pincus and Tom Hamill.

(2) **Scale and aerosol aware stochastic convective parameterization:** The Grell-Freitas parameterization already has been implemented in the GFS physics package, using the FIM. During the first year we will fine tune the stochastic aspects on different horizontal resolutions ranging from approximately 15km to 60km. Evaluation will be performed with commonly used evaluation metrics as used by EMC. The second year may include tests on convection permitting scales with non-hydrostatic global model cores, as well as research with the aerosol aware component of this parameterization. This will be done with GOCART aerosol

modules, which are also used in the GFS. At the end of the second year we expect to finish peer-reviewed publications on all aspects of the parameterization as tested and evaluated within the GFS physics suite.

Second Quarter of FY14:

- Hire of CIRES scientist

Fourth Quarter of FY14:

- Tuning of stochastic convective parameterization using EMC evaluation metrics finished

Second Quarter of FY15:

- Implementation and evaluation of aerosol awareness using observed and simulated AOD completed

Fourth Quarter of FY15:

- Evaluation of scale awareness for case studies and shorter periods in non-hydrostatic modeling system finished
- Peer reviewed publication submitted

Tolerances

NCEP expects the next major implementation of the GFS model and assimilation system will be late in Q1FY2016. Following their procedure, typically 6-9 months prior to this, decisions are made about what components should be included in the operational implementation, the code is frozen, and parallel testing ensues. Accordingly, testing for the unified turbulence/cloud parameterization should be complete by 2015. In late 2014, we expect our participants for this component to have successfully demonstrated an improvement to the GFS using the new parameterization. If not, that is a point for re-evaluation.

Dependencies

The successful implementation of the unified cloud/turbulence parameterization depends on buy-in from personnel at NCEP/EMC. While our staff can and will provide every bit of evidence possible to make an informed decision that ultimate decision is up to NCEP/EMC staff. Funding for this parameterization development will come in year 1 from HIWPP, but thereafter from the Climate Process Team, so the successful implementation in part assumes that there will be no further funding delays for that team.

Similar to the unified cloud/turbulence parameterization, implementation of the scale and aerosol aware stochastic convective parameterization (or parts of it) also depends on buy-in from personnel at NCEP/EMC.

Risks

For the unified cloud/turbulence parameterization, it is worth noting that the NOAA Climate Program Office funded two Climate Process Teams, each working on different cloud parameterization methods. The other team, headed by Chris Bretherton at the University of Washington, proposes more evolutionary advances. It will be out of the control of HIWPP staff as to which of the two, if either, is used in the GFS and GEFS.

This effort will be attempting to overhaul GFS parameterization suite code, which potentially may not be well suited to the purposes of this task; this could add significant time to the project, attempting to understand the existing code and restructure it.

Scheduling
See above.

Budget
Detailed budgets provided under separate cover.

References
Grell, G. A., and S. R. Freitas, 2013: A scale and aerosol aware stochastic convective parameterization for weather and air quality modeling. *Atmos. Chem. Phys. Discuss.*, **13**, doi:10.5194/acpd-13-23845-2013.

3.1.3 Global Forecast System (GFS)

Task Lead: Yuejian Zhu (NCEP/Environmental Modeling Center)

Introduction
The development is intended to evaluate potential enhancement of the operational North American Ensemble Forecast System (NAEFS) forecast products through the addition of FIM and/or FNMOC ensemble members. The 33 km NCEP global ensemble forecast system (GEFS) will be run retrospectively for one year. These retrospective forecasts will be combined with the FIM and evaluated as per the NAEFS test plan (see sub-task below).

Outputs & Deliverables
The plan is to run one-year retrospective forecasts with the NCEP GEFS. The GEFS retrospective forecasts will be combined with similar retrospective forecasts from the FIM and evaluated as per the NAEFS test plan. A report of the evaluation will be prepared for consideration by project management.

Quality Criteria
The planned retrospective runs have been completed, the statistical post-processing has been applied and the multi-model ensemble products have been evaluated.

Resources
NCEP/EMC will hire two contract scientists to run these retrospective forecasts experiments on NOAA R&D HPC, and evaluate the multi-model ensemble products as outlined in the NAEFS test plan.

Management
This task will be coordinated with ESRL on the FIM ensemble retrospective runs. There will be monthly meeting between NCEP and ESRL scientists to exchange the information and report on progress. The EMC Director will be kept apprised of all aspects of this project.

Milestones
First – Second Quarter of FY14:
- Hire and train the support scientists, start to collect GEFS initial conditions (1-year) including initial perturbations

Third Quarter of FY14:
- Start the retrospective forecasts

Fourth Quarter of FY14:
- Exchange the forecast data with partners and begin statistical post-processing

First Quarter of FY15:
- Finish the retrospective runs, continue data exchange and statistical post-processing, and start the multi-model evaluation and verification

Second Quarter of FY15:
- Finish the statistical post-processing; continue evaluation and verification, finish exchange of data

Third Quarter of FY15:
- Finish the evaluation and verification. Start comparison of experimental NAEFS including the FIM ensemble with operational NAEFS

Fourth Quarter of FY15:
- Finish the comparison of experimental NAEFS including FIM ensemble and the operational NAEFS. Write summary report, and/or scientific manuscript

Tolerances
Possible slippage in meeting milestones for this project could result from inability or delay in hiring suitable support scientists, insufficient computing resources on NOAA R&D systems, and insufficient bandwidth for forecast data exchange between NCEP and ESRL.

Dependencies

This task is highly coordinated with ESRL. It can only be completed when both GEFS and FIM ensemble retrospective forecasts are finished and the forecast data is exchanged.

Risks

Risks include:
1. Inability to find suitable support scientists.
2. Insufficient computing resources to complete this task.

Scheduling

See above.

Budget

Detailed budgets provided under separate cover.

Sub-task: Plan for Possible Inclusion of FIM in NAEFS

Background: The Directors of NCEP and ESRL signed a Letter of Agreement (LOA) in November 2008 regarding the testing of the FIM for possible inclusion in the NAEFS MME forecasting system. Discussions have been ongoing since 2010 between NCEP and ESRL, as both FIM and GFS have matured. More recently (October 2012), a draft Test Plan has been developed between NCEP/EMC and ESRL/GSD for evaluation of FIM for possible inclusion in NAEFS. To date, FIM has never been formally evaluated for inclusion in NAEFS or in the NOAA-only GEFS. Given the long delay from the signing of the original LOA and subsequent evolution of the operational modeling suite, this document seeks to combine the relevant aspects of the original LOA with the draft Test Plan from October 2012 into a single document for reference by ESRL and NCEP. It is anticipated that this document will also serve as a reference for the HIWPP Hydrostatic Ensemble project. A recommendation for completion of the terms of the LOA is outlined in the last section of this document.

Model Configuration: GEFS will be tested at a resolution of 35 KM. It is anticipated that FIM will be tested at a similar resolution. As mentioned in the Computational Efficiency section, the model resolution used for FIM will need to be chosen so that it can fit in the NCEP Production Suite resource window for processors, memory, and timing occupied by the operational 35KM GEFS system.

Test Protocol: Retrospective forecasts of length 16 days starting from the 00Z cycle for an ensemble of 10 members for each day for one full calendar year for each system.

Fields to be Exchanged: NAEFS variables. See Table 1.

Format of Model Output: NAEFS format (GRIB). Data will be exchanged on a 1° x 1° grid.

Verification Data: Operational NCEP GDAS analyses and ECMWF analyses will be used for verification except for precipitation, which will use CCPA and tropical cyclone track which will use TCVitals**.**

Initial Condition Data: Operational GSI-Hybrid assimilation system.

Evaluation Strategy for New Systems: The baseline skill level will consist of the MME formed by equally weighting the GEFS and MSC ensemble forecast system (NAEFS system) for deterministic scores and using all ensemble members from the GEFS and MSC ensembles for probabilistic scores. The change in skill will be measured by forming a new MME including the CMC ensemble plus 10 members from the GEFS and 10 members from the FIM with weights determined by relative ensemble size for deterministic scores (0.25 for GEFS and FIM ensemble means, respectively and 0.5 for MSC ensemble mean) and equal weighting for all ensemble members from all systems for probabilistic scores. Evaluation will also be made for a NOAA-only ensemble comparing skill of the current GEFS with its 20 members vs. a multi-model version with 10 members each from GEFS/GFS and FIM.

Bias Correction/Statistical Post-Processing: Each model will be individually bias-corrected using the operational NAEFS technique before being combined with the other models.

Skill Evaluation:

- Primary fields and skill metrics given in Table 2
- Acceptable performance for secondary variables such as stratospheric ozone and temperature, and tropospheric moisture
- Candidate models will also be evaluated to ensure that they do not produce any substantial degradation in objectively determined forecast skill for any other operational field
- Subjective evaluation by the following NCEP Service Centers: WPC, CPC, SPC, AWC, NHC, and OPC

Computational Efficiency:

The FIM will be run at a resolution that fits into NCEP Production Suite resource window for GEFS for each of the following computer resources:

- Processors
- Memory
- Wall clock

Sustainability: The FIM will need to meet the following requirements.

- Meets (negotiated) requirements for response to emergencies (e.g. system failures)
- Capable of progressive future upgrades by NCEP/EMC and partners
- Written in standard languages (Fortran, C, C++, and other languages with mutual agreement)

- Uses minimum code structure complexity to meet operational mission and anticipated future requirements
- Code is sustainable by NCEP staff and can be fully understood, navigated, and modified without excessive difficulty
- Contains inline documentation in NCEP standard format
- Adaptable to NCEP's changing computing environment and portable to major computing architectures
- Conforms to the NCEP code management system (e.g. "Subversion")

Recommendation on Implementation of FIM into NAEFS: As noted in the original LOA, the directors of NCEP/EMC and ESRL/GSD will advise the NCEP and ESRL Directors on the suitability of the FIM for incorporation into NAEFS. If the FIM is not accepted for inclusion into NAEFS after these tests have been performed, it is recommended that the LOA be considered to have been executed and any future evaluation of FIM for possible inclusion in NAEFS will need to be governed by the signing of a new agreement between NCEP and ESRL management.

Table 1 NAEFS Variables

Variable	Description
Geopotential	Vertical levels (hPa): 1000, 925, 850, 700, 500, 250, 200, 100, 50, 10; Surface
Temperature	Vertical levels (hPa): 1000, 925, 850, 700, 500, 250, 200, 100, 50, 10; 2 meter, 2 meter maximum, 2 meter minimum
Relative Humidity	Vertical levels (hPa): 1000, 925, 850, 700, 500, 250, 200, 100, 50, 10; 2 meter
Zonal Wind	Vertical levels (hPa): 1000, 925, 850, 700, 500, 250, 200, 100, 50, 10; 10 meter
Meridional Wind	Vertical levels (hPa): 1000, 925, 850, 700, 500, 250, 200, 100, 50, 10; 10 meter
Pressure	Surface, mean sea-level
Precipitation	Total accumulated, precipitation type (4 categories): Rain, snow, freezing rain, ice pellet
Fluxes at Surface	Latent heat flux, sensible heat flux, downward shortwave, downward longwave, upward shortwave, upward longwave
Fluxes at Top of Atmosphere	Upward longwave (OLR)
Precipitable Water	Total precipitable water in column
Cloud Cover	Total cloud cover
Convective Instability	Convective available potential energy (CAPE), convective inhibition (CI)
Land Surface	Soil wetness (upper 10 centimeters), soil temperature (upper 10 centimeters),
Snow	Water equivalent of accumulated snow, snow depth
Vertical Velocity	850 hPa

Table 2: Fields for Skill Evaluation

Variable	Levels	Area	Scores	Forecast Range (Hours)
Height	500 hPa	NH, SH	ACC, RMSE, Spread CRPS	0 to 384
Height	1000 hPa	NH, SH	CRPS	0 to 384
Temperature	850 hPa	NH, SH	CRPS	0 to 384
Pressure	Surface	NH, Tropics	Track Error	0 to 120
Winds	850, 200 hPa	NH,Tropics	CRPS, RMSE	0 to 384
Precipitation		CONUS	ETS, CRPS, Bias	0 to 384
Temperature	2 meter	NH	CRPS	0 to 384
Winds	10 meter	NH	CRPS	0 to 384

Geographic masks will be applied for 1000 hPa heights to remove higher-elevation regions where variations in reduction to sea level may obscure meaningful results.

3.1.4 Flow-Following, Finite Volume Icosahedral Model (FIM)

Task Lead: Stan Benjamin (ESRL/GSD)

Introduction

The aim of this task is described under the Task 3.1 overview – to provide an experimental global model benchmark with high-resolution experimental global models to compare with future non-hydrostatic global model skill, to accelerate development of model components (physics, DA, ensemble configuration, numeric), and to accelerate improvement of NOAA operational global models. ESRL will provide high-resolution (10-15km) deterministic FIM model runs and moderate resolution 10-member ensembles (30-60km) FIM forecasts for both retrospective and quasi-real-time evaluation venues as planned for the High-Impact Weather Prediction Project (HIWPP). ESRL will also develop improvements to physics, data assimilation, numeric and ensemble suitability with the FIM model.

NOAA Earth System Research Laboratory is well positioned to contribute to goals of HIWPP's hydrostatic global model component (section 3.1) with the development of the Flow-following finite-volume Icosahedral Model (FIM) with an innovative icosahedral horizontal and quasi-Lagrangian vertical grid structures. ESRL has developed the FIM model in collaboration with EMC in its use of GFS physical parameterizations and GFS initial conditions. ESRL has worked closely with EMC in evaluation of the FIM model vs. the GFS model using EMC's global verification package.

Outputs and Deliverables

ESRL will conduct 12-month retrospective forecasts of FIM deterministic forecasts at high resolution (10-15km out to 10 days) and ensemble forecasts (10 members at both 30km and 60km resolution out to 16 days). ESRL will make output from these retrospective test forecasts available to the Task 3.1 hydrostatic global model team and Task 3.5 test program areas as appropriate. ESRL will ensure that the model output meets current NAEFS/NUOPC protocols. ESRL will produce quasi-real-time products as appropriate and as computational resources allow. ESRL will also coordinate with other Task 3.1 (especially Task 3.1.1 (assimilation/ensemble /stochastic physics) and Task 3.1.2 (parameterization development)) and Task 3.5 team members in evaluation of multi-model ensemble forecasts.

Quality Criteria

ESRL will ensure that FIM forecasts contribute to deterministic and ensemble forecast skill, that retrospective and real-time forecasts run to completion, and that the output is accessible to collaborators.

Resources

Human: ESRL will hire a scientist to assist with FIM model development and conducting retrospective deterministic and ensemble tests. Other members will include: Stan Benjamin (management, model development), Shan Sun and Rainer Bleck (model development), Judy Henderson (model testing), and Ed Szoke (model evaluation).

Computational resources: Zeus and Jet. It may be necessary to obtain other computational resources depending on the initial availability of the Zeus-2 expansion.

Management

Coordination and overall management of this FIM task will be provided by Stan Benjamin. Shan Sun and Rainer Bleck of ESRL will lead model development. ESRL will coordinate with NCEP/EMC on development of FIM ensemble forecasts and incorporation into the experimental NAEFS. The FIM HIWPP team will closely coordinate with all other HIWPP points of contact as shown below.

What	Who's Responsible	Target Audience	Method
Project Plan	3.1 POC, Benjamin	3.1, 3.2, 3.5 & Project Mgr.	Document
Status Reports	3.1 POC, Benjamin	3.1, 3.3 3.5 & Project Mgr.	Document, Status Report Template
Project Advisory Group	3.1 POC, Benjamin/ 3.2 and 3.5 Test Mgrs., Project Mgr.	ESRL Lab Director	Meeting
Technical Team	3.1 POC, Benjamin	Technical Team	Project

Meetings			Management Plan
Sponsor Meetings	ESRL Lab Director, Project Manager, 3.1 POC, Test Mgr. & 3.5.3 POC Weygandt	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.1 POC, Benjamin, 3.5.3 POC, Weygandt, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, ESRL Lab Director, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Milestones

Second Quarter of FY14:

- Identify team participants, computer resources, and determine FIM model configurations for hydrostatic tests.

Third Quarter of FY14:

- Begin retrospective runs of FIM hydrostatic model for deterministic and ensemble forecasts.
- Initial FIM verification results produced for retrospective runs of hydrostatic models (retrospective runs continue) [EMC, Navy, ESRL]
- Coordinate with HIWPP Verification team (section 3.5.3) on evaluation of retrospective FIM deterministic and ensemble forecasts and other Tasks 3.1 models from each participating laboratory

First Quarter of FY15:

- By mid-November, retrospective runs over 1-year period of FIM model for deterministic and ensemble forecasts are complete.
- In October, participate in decision made based on initial retrospective results on hydrostatic model for quasi-real-time ensembles. Quasi-real-time forecasts from all HIWPP hydrostatic models will be made available for deterministic and ensemble forecasts through HIWPP. A decision on ensemble membership for the HIWPP extended/experimental NAEFS and mini-ensemble from high-resolution models will be made by a working group {ESRL, EMC, Navy members).
- Configuration is finalized for quasi-real-time experimental FIM hydrostatic model forecasts anticipated at 10-15-km resolution.
- Configuration is finalized for quasi-real-time experimental multi-model forecasts using FIM with GFS and NAEFS members.

Second Quarter of FY15:

- January: Start of quasi-real-time experimental forecasts from FIM model at 10-15-km resolution
- January: Start of quasi-real-time ensemble forecasts (0-16 days) from FIM model and coordinate with NAEFS colleague Task 3.1 team members (EMC, Navy)
- With other HIWPP Task 3.1 and Task 3.5 members, collect and synthesize feedback from beta testers on their impressions of real-time demonstration of hydrostatic models.

Third Quarter of FY15:

- Continue quasi-real-time experimental runs from FIM models at 10-15-km resolution
- Continue quasi-real-time experimental ensemble forecasts (0-16 days) from FIM hydrostatic model (at anticipated 30km resolution)

Fourth Quarter of FY15:

- Continue quasi-real-time experimental runs from FIM model at 10-15-km resolution
- Continue quasi-real-time experimental ensemble forecasts (0-16 days) from FIM hydrostatic model (at anticipated 30km resolution)
- With other Task 3.1 labs, produce draft report on hydrostatic real-time tests.

Second Quarter of FY16:

- Complete quasi-real-time experimental runs from FIM model at 10-15-km resolution
- Complete quasi-real-time experimental ensemble forecasts (0-16 days) from FIM hydrostatic model (at anticipated 30km resolution)
- With other Task 3.1 team members, submit report on hydrostatic model real-time test results to a peer-reviewed journal.

Tolerances

The ESRL team for the FIM model is in a fairly good position for meeting its milestones. A delay of 1-3 months in the completion of retrospective tests is possible, as is the beginning of the quasi-real-time testing using the late-2014 updated version of the FIM model. The development of the FIM ensemble data assimilation (using GSI possibly with HIWPP-funded DA enhancements) may also suffer from some delays of a few months.

Dependencies

The FIM Task 3.1 activity will depend very heavily on Task 3.5 verification activities, on EMC for ensemble testing for experimental NAEFS and multi-model GEFS configuration.

Risks
Hiring of additional global modeler.
Insufficient computing resources especially for ensemble forecast.

Scheduling
See above

Budget
Detailed budgets provided under separate cover.

3.1.5 Navy Global Environmental Model (NAVGEM)

Task Lead: Melinda Peng,
Team Members: Carolyn Reynolds, and Timothy Whitcomb

Introduction
This task will provide high-resolution deterministic NAVGEM and moderate resolution 10-member ensemble NAVGEM forecasts as part of the HIWPP 3.1 Hydrostatic Global Models effort. Toward this end, NRL-Monterey will participate and contribute their model development effort to reach the goals of 1) Establishing advanced hydrostatic model benchmarks by which to measure performance of upcoming global non-hydrostatic models and 2) Improving hydrostatic-scale medium-range forecast capability via advanced models and ensembles.

Global model prediction capability is the foundation of all numerical weather prediction. Traditionally, global models have been run at relatively coarse resolution, while high-resolution simulations have been the domain of limited-area models run for short time periods. With the increasing computational capability, high-resolution global model has become more and more affordable in the operational environment. Furthermore, running global models at high resolution has the potential to address the "week two" forecast problem through skillful simulations of complex multi-scale phenomena, such as the Madden Julian Oscillation, that can provide predictability on these extended time scales. However, at these longer timescales, probabilistic prediction becomes essential, as expected predictability may vary greatly from week to week. A multi-model forecast system is the best way to tackle this problem, as several efforts (e.g., the North American Ensemble Forecasting System and the National Unified Operational Prediction Capability) have shown that multi-model ensembles provide superior performance over single-model ensembles. These multi-model ensembles offer a better representation of model error, and therefore provide superior performance as measured by deterministic and probabilistic metrics. Multi-center ensembles also allow for leveraging of computational resources at multiple organizations, which provides higher-resolution ensembles than would be feasible at individual centers.

NRL-Monterey is well positioned to contribute to the task as the central test site for the new development of physical parameterization of two ONR Direct Research

Initiatives (DRIs) under which the modeling community is working toward improving physics suitable for multi-scale processes. A recent success is the eddy diffusivity-mass flux turbulence-mixing scheme developed by JPL and implemented into NAVGEM. The NAVGEM team will work with EMC and ESRL and the community on various components of model physics with optimal model resolution.

Outputs & Deliverables

NRL-Monterey will produce yearlong reforecasts of high resolution deterministic NAVGEM (approximately 25 km), and 10-member NAVGEM 16-day ensembles (approximately 35 km). Output from these reforecasts will be made available to the Task 3.1 hydrostatic global model team and Task 3.5 test program areas as appropriate. Model output will be adapted to meet current NAEFS/NUOPC protocols. After evaluation of the reforecasts, quasi-real-time products will be produced as appropriate and as computational resources allow.

Quality Criteria

For the retrospective forecasts, quality criteria will be that the forecasts run to completion, give physically realistic results, and that the output is accessible to collaborators.

Resources

The team will be composed of Tim Hogan (global modeling expert), Tim Whitcomb (configuration management expert), Justin McLay and Carolyn Reynolds (ensemble expertise) and Melinda Peng (modeling expert, lead of NAVGEM, and NRL Atmospheric Modeling and Dynamics Branch Head).

Computational resources will consist of platforms within DoD and NOAA. NRL-Monterey will utilize computational platforms at the Navy DoD Supercomputing Resource Center (Navy DSRC), which is a leading provider of high performance computing services and support to the DoD scientists and engineers. It is one of five supercomputing centers established under the auspices of the DoD High Performance Computing Modernization Program (HPCMP). The Navy DSRC leverages high performance computers and a wealth of knowledge to greatly improve the computational research environment for DoD researchers. The center also provides leadership for HPCMP-wide functions including remote petascale data storage, enterprise systems monitoring, and remote system and database administration. The Navy DSRC platforms include two IBM iDataPlex systems, Haise and Kilrain (435 TFLOPS each), and a Remote Mass Storage Server (RMSS) system (composed of a single Oracle T4-4 server named Newton). NRL-Monterey will also utilize the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, which is the premier research and development laboratory complex for the Corps of Engineers. NRL-Monterey will primarily utilize the Cray XE6, Garnet, which is a 1.5 PFLOPS platform and consists of 4716 compute nodes (32 cores per node).

To address the task plan, NRL-Monterey will likely need to obtain additional computational resources from the DoD HPCMP, as well as NOAA computational platforms. NRL-Monterey has requested NOPP HPC resources, which will facilitate timely completion of retrospective and quasi-real-time runs.

Management

Oversight of the coordination and technical aspects of this task will be provided by Tim Whitcomb at NRL. This will be accomplished through regular (monthly) meetings with those on the NRL team to organize the deterministic high-resolution forecasting effort, led by Tim Hogan, and the ensemble forecasting effort, led by Carolyn Reynolds and Justin McLay. Melinda Peng will oversee the effort on a programmatic level and coordinate with the other HIWPP task leads and the project manager through regular updates via phone and email. The NRL superintendent, Simon Chang, is serving on the HIWPP Executive Oversight Board and will provide broad oversight of the project as needed.

What	Who's Responsible	Target Audience	Method
Task Plan	3.1.5 POC, Peng	3.1, 3.2, 3.5, & Project Mgr.	Document
Status Reports	3.1.5 Technical POC, Whitcomb	3.1, 3.3 3.5 & Project Mgr.	Document, Status Report Template
Technical Team Meetings	3.1.5 Technical POC, Whitcomb	Technical Team	Project Management Plan
Periodic Demos and Target Presentations	3.1.5 Technical POC, Whitcomb, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, NRL Superintendent, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Project Management Guide

Responsibilities of the NAVGEM task: POC/Technical Lead: Melinda Peng, Tim Whitcomb

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team
- Provide requirements understanding and guidance to the development team
- Identify Deterministic and Ensemble development teams
- Establish communication plan and schedule with other HIWPP POC's
- Develop tasking, schedule and budget the NAVGEM 3.1.5 task

- Coordinate with other HIWPP project areas to leverage meetings, demonstrations and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting and critical develop monitoring and guidance

Milestones

First Quarter of FY14:

- Port the high-resolution NAVGEM deterministic and ensemble systems to the appropriate computer system(s)

Second – Third Quarter of FY14:

- Improve NAVGEM dynamic core and model physics toward the targeted resolutions

FY15 through Second Quarter of FY16:

- Adapt and test software to produce forecast model output in appropriate format (using existing NAEFS/NUOPC protocol)
- Examine limited (few weeks) retrospective runs for quality control and format of output (working with other hydrostatic global model and test program groups)
- Run high-resolution and ensemble NAVGEM for the full retrospective (year-long) time period
- Pending evaluation of quality of both the ensemble and high-resolution NAVGEM forecasts in collaboration other task areas, begin quasi-real-time ensemble and high-resolution forecasts
- Participate in evaluation of multi-model ensemble forecasts

Tolerances

Retrospective runs: Once the NAVGEM systems are ported to the appropriate computer systems, and the retrospective runs have started, forecast through-put will be evaluated. If computer resources are limited, through-put may be too slow for a completion of the retrospective runs. At this time, the experimental set-up will be re-evaluated (e.g., run at lower resolution, fewer ensemble members, or lengthen the time intervals between retrospective forecasts). After the retrospective runs are completed for at least a few months, an intermediate evaluation of forecast skill will facilitate future planning for the multi-model ensemble configuration.

Quasi-real-time Runs: The quasi-real-time runs will be very dependent upon availability of sufficient computational resources at a specific time of day every day. The availability of such resources is an open question right now. In addition, a large amount of data will need to be transferred to the collection points, and data transfer speeds may not be sufficient to deliver the results in a reasonable amount of time. After the start of the quasi-real-time runs, the configuration of these runs and the format and amount of forecast output may be re-evaluated in order to meet real-time constraints.

Dependencies

The largest dependency will be on availability of computational resources, especially for the quasi-real-time runs, but also for the retrospective runs. NAVGEM forecast model and ensemble development projects at NRL will be leveraged. NRL-Monterey will leverage the work of the Fleet Numerical Meteorology and Oceanography Center in their development of software to produce ensemble forecast output in the NAEFS/NUOPC format. Work on this project will depend on the other hydrostatic modeling centers in the production of the multi-model ensemble forecasts, although examination of the utility of the multi-model ensembles may continue even if the number of contributing models is smaller than expected. There is also a dependence on the statistical post processing effort to evaluate the retrospective runs. Project deliverables will depend on the visualization and extraction NEIS effort to optimize use of the multi-model ensemble forecasts. There is also dependence on the verification methods effort to provide methods to evaluate the multi-model ensemble efforts.

Risks

The largest risk is on the availability of computational resources, especially for the quasi-real-time runs. In addition, the performance of NAVGEM at 25 km resolution has not yet been examined. It is anticipated that significant efforts need to be devoted to improving the sub-grid scale physics that matches the higher resolutions. These risks may be mitigated by re-evaluation of the experimental design, as noted above (e.g., run the forecasts at lower resolution, include fewer ensemble members).

Scheduling

See above.

Budget

Detailed budgets provided under separate cover.

3.2 Non-Hydrostatic Global Models

Workgroup Lead: Jeff Whitaker (ESRL/PSD)

A primary goal of this project is to develop a global cloud-permitting (~3km resolution) forecast capability.

This activity will focus on the testing and evaluation of global non-hydrostatic dynamical cores under development at EMC, GFDL, ESRL, NPS/NRL and NCAR to assess their potential for achieving the project goals. The following milestones will be required for all participants:

Year 1:

- 6/1/2014: Baroclinic wave DCMIP test case 4.1.0 will be delivered to Task Lead (specific configuration and required output to be determined collaboratively with task participants).

- 7/1/2014: Orographic gravity wave test case on a scaled small planet will be delivered to Task Lead (specific configuration and required output to be determined collaboratively with task participants).

- 8/1/2014: Idealized supercell test case on a scaled small planet will be delivered to Task Lead (specific configuration and required output to be determined collaboratively with task participants).

- 9/1/2014: Optional – Tropical cyclone test case (DCMIP 5.1) will be delivered to Task Lead (specific configuration and required output to be determined collaboratively with task participants). This milestone is deemed optional in recognition that the late arriving funds and associated delays in hiring staff may preclude some groups from conducting this test.

- 10/1/2014: A report synthesizing the results of the submitted tests will be prepared by the Task Lead (with input from all the task participants) and submitted to the Project Manager.

Year 2:
During year 1 of HIWPP a new project, the Next Generation Global Prediction System (NGGPS), was funded to design, develop, and implement the next operational global prediction system. In order to maximize efficient use of resources and to expedite progress toward the next-generation system, HIWPP and NGGPS efforts are being coordinated and aligned.

Part of the NGGPS effort is to evaluate, select and implement a non-hydrostatic model to replace the current GFS hydrostatic global model. NGGPS will build on the deliverables from HIWPP to evaluate candidate non-hydrostatic models.

An additional goal of the NGGPS project is to fully utilize evolving High Performance Computing capabilities, and, to this end, the Advanced Computing Evaluation Committee (AVEC) was formed. Outputs from Task 3.2.3, the Massively Parallel Fine Grain (MPFG)/GPU Optimization, will be leveraged in this NGGPS effort, and will be coordinated with the efforts of AVEC.

In order to best align the objectives and deliverables of these 2 projects, the year 2 milestones for the non-hydrostatic sub-project were re-evaluated and modified. In this phase of the project, the focus will shift from idealized test cases to evaluating the models in the context of real-data global forecasts:

- 11/30/2014: Each modeling group will deliver a package of code and datasets to AVEC for Level-1 benchmark evaluation of performance, scaling, software design, and HPC readiness.

- 2/15/2015: Final suite of benchmark codes will be ready to begin testing.

- 3/1/2015: 2-3 day global forecasts at 3km resolution, initialized from the NCEP GDAS analysis. These forecasts will be of shorter duration and for a very limited number of cases chosen to highlight specific phenomena (such as mesoscale convective systems and hurricanes). The forecasts will be initialized from operational global analyses, and will be run with 3km global orography and high resolution boundary datasets (to represent the land and ocean surface conditions). Explicit microphysics will be used (no cumulus parameterization). These tests will demonstrate the ability of the models to deal with high-resolution orography and surface conditions, in the presence of complex microphysics and radiation. Forecasts will be evaluated subjectively to assess the realism of the simulated phenomena. In addition, these tests will evaluate the ability of the models to scale up to the tens of thousands of CPU cores, since this will be necessary to complete these runs in a reasonable amount of wall clock time. We recognize some participants may lack the HPC resources to perform these tests in a timely manner. We will advocate that new HPC resources procured with Sandy Supplemental funds should be dedicated to these tests, for a short period after their initial delivery (sometime in early FY15).

- 5/1/2015: A report will be delivered summarizing the idealized and 3-km real data forecasts plus AVEC benchmark results produced jointly with NGGPS. This report will be used by NWS for a preliminary down-select of dynamical cores for further testing. This report will also be used to decide which model or models will be the focus of further HIWPP funded development in year 3, including data assimilation and ensemble development (section 3.1.1), parameterization development (section 3.1.2) and MPFG/GPU optimization (section 3.2.3).

- 10/1/2015: Level-2 testing of the selected dynamical cores will be completed in conjunction with NGGPS, with further details on testing to be determined.

The following sub-sections describe the development and testing/evaluation that are necessary to achieve this goal.

3.2.1 Assimilation/Ensembles/Stochastic Physics

See section 3.1.1, wherein the hydrostatic and non-hydrostatic aspects of this task are described jointly.

3.2.2 Parameterization Development

See section 3.1.2, wherein the hydrostatic and non-hydrostatic aspects of this task are described jointly.

3.2.3 Massively Parallel Fine Grain (MPFG)/GPU Optimization

Task Lead: Mark Govett

Introduction

A new generation of high-performance computing has emerged called Massively Parallel Fine Grain (MPFG). MPFG computing falls into two general categories: Graphics Processing Units (GPUs) from NVIDIA and AMD, and Many Integrated Core (MIC) offered by Intel. These chips are ten to fifty times more powerful than CPUs. Rather than 12-16 powerful cores found in CPUs, they rely on hundreds to thousands of simple compute cores to execute calculations simultaneously. In addition to higher performance, MPFG chips also consume less power per floating-point operation (flop) making them an attractive, energy-efficient alternative to CPUs.

Large increases in compute power do not map directly to real application performance however. Performance gains can only be achieved if fine-grain or loop level parallelism can be found and exploited in the applications. Fortunately, weather and climate codes generally contain a high degree of parallelism but minor to substantial modifications may be required to expose it, changes that will likely also improve CPU performance. For example, researchers at ESRL have demonstrated 2x improvements in CPU performance through code changes, which led to a further 3x boost in performance on the GPU.

To meet a core HIWPP goal of developing and running global non-hydrostatic models at cloud-permitting 3-4 km horizontal resolution, MPFG computing is essential. At this resolution, a minimum of 100,000 CPU cores would be required, but only an estimated 2000 GPUs or MIC processors are necessary. Procurement of such a system with HIWPP funds, targeted for mid FY2015, will likely include technology improvements including (1) integration of the CPU and MPFG onto a single chip (2) increases in on-chip memory, (3) performance improvements in inter-MPFG chip communications, and (4) improved programmability with the openACC and openMP compilers. Chip integration likely will yield the biggest benefit as it will simplify programming and improve performance by eliminating data transfers between CPU and GPU or MIC chips.

In FY2014, tasking under HIWPP will focus on the parallelization and optimization of the NIM and FIM models for MPFG. While the FIM model is not a non-hydrostatic model, its parallelization and optimization will benefit from increased performance and yield useful real-data forecasts and aid parallelization/optimization of other models, especially those with unstructured horizontal grids. During this year, significant work will be done to prepare global models for benchmarks in support of the FY2015 procurement (commencing in FY2014), with the goal to run the entire model, physics and dynamics, on GPU and MIC devices. Since FIM and NIM dynamics already run on GPU and MIC, we will primarily focus on porting the physics. Specifically, the GFS physics will be parallelized for both NVIDIA GPU and Intel MIC. Porting these applications will also benefit other models that use the same physics routines.

MPFG parallelization will proceed in three stages. First, code will be analyzed and modified as needed to expose loop level parallelism, improve data organization to optimize memory accesses, reduce branching, and other optimizations. Every attempt will be made to demonstrate there are no changes in model results, but we anticipate some algorithmic changes may prove beneficial. All changes will be reviewed for clarity and accuracy by the modelers before being accepted. Our experiences have demonstrated these optimizations are beneficial to both CPU and MPFG architectures.

Second, industry-standard openMP and openACC directives will be inserted into the Fortran codes for MIC and GPU parallelization. The openMP standard is used with Intel's MIC system, while the openACC standard is used with the PGI, Cray and CAPS compilers for the GPU systems. The NIM and FIM models currently use a compiler developed at ESRL called F2C-ACC. This compiler was developed before commercial Fortran GPU compilers were available, and it continues to be used to run FIM and NIM, to demonstrate performance results and to push for improvements in the openACC compilers. F2C-ACC and openACC directives are very similar so code conversion can easily be done once commercial compilers are ready. ESRL will continue to evaluate the openACC compilers, and collaborate with vendors on improvements to support NOAA models

Model optimization and scaling to thousands of Fine-Grain nodes will be the focus of the final stage in parallelization for MPFG. Performance improvements thru testing and profiling will help determine bottlenecks, communications optimizations, and I/O improvements. Given that NOAA will not have a large MPFG system until FY2015, testing will be done on the MIC-based TACC and NVIDIA-based Titan systems as resources permit.

In FY2015, further work on FIM and NIM is expected to keep abreast of model development, architectural changes for the MPFG machines, and performance tuning. There will be an increasing focus on the leading non-hydrostatic model(s) and model components being developed and evaluated under HIWPP. Evaluation of the non-hydrostatic models, including DCMIP and real-time tests, portability and scalability potential, and other criteria will further refine where additional MPFG parallelization and porting efforts will occur. It is envisioned that commonality between the NIM and MPAS models, including the icosahedral grid structure, indirect array addressing, and model physics, make this a leading candidate for collaboration and work on MPFG parallelization.

Outputs & Deliverables

- FIM dynamics + GFS physics running on GPU and MIC
- NIM dynamics + WRF-ARW physics running on GPU and MIC
- MPAS dynamics or another leading non-hydrostatic model running on GPU and / or MIC – completion dependent on model complexity, scientific support, and available staffing.

Quality Criteria

With next-generation hardware procured in FY2015, we believe the non-hydrostatic models will benefit from a 2x performance boost over current generation Kepler GPU, and Intel MIC. It is also likely that similar performance gains are possible in conventional CPU chips, thus maintaining the 3x performance edge we have observed in CPU to GPU comparisons to date with the NIM model. Further, we believe openACC and openMP compilers will have matured sufficiently to simplify porting of codes to MPFG, while permitting performance portability in a single code base.

Resources

Computational:

- TACC – MIC cluster, Titan GPU clusters with limited allocation
- Gaea-T3 GPU cluster for smaller 30 km model resolution runs

Staffing:

- Tom Henderson: GPU and MIC parallelization and optimization
- Jacques Middlecoff: GPU parallelization and optimization, inter-GPU communications optimizations
- Jim Rosinski: MIC & openMP parallelization
- Paul Madden: Application performance analysis, tools development
- New hire: Graduate / under-graduate for testing & support

Management

- Task managed by task lead (Mark Govett)
- Coordination with non-hydrostatic task lead (Jeff Whitaker) and hydrostatic model lead (Stan Benjamin)
- Once regular runs begin in FY2015, coordination with ITS (Bob Lipschutz) and visualization with NEIS (Jebb Stewart) is expected

Milestones

Second Quarter of FY14:

NIM benchmark code ready for MPFG procurement

First Quarter of FY15:

- NIM dynamics optimized for MPFG to thousands of nodes using TACC and ORNL resources

Second Quarter of FY15:

- MPFG parallelization of GFS Physics to FIM and NIM for Intel MIC and NVIDIA GPU; integrate with dynamics, test on TACC and ORNL

Third Quarter of FY15:

- Computational benchmark tests prepared and run jointly with NGGPS for non-hydrostatic dynamical cores by April, 2015

Fourth Quarter of FY15:

- Updated MPFG parallelization of latest FIM, NIM models

First through Fourth Quarter of FY16:

- Optimize performance of FIM, NIM and begin runs on new MPFG system
- Continue MPFG parallelization of MPAS or other non-hydrostatic model (dependent on scientific evaluation)

Tolerances

The pace of NIM model development and adoption of code changes we make by developers will temper our ability to optimize parallel performance at 3.5 km resolution. If the model is not ready scientifically, we will not make runs on Titan as planned in mid FY2014.

Dependencies

MPFG parallelization: FIM, NIM model development, adoption of recommended code changes by modeling teams

Computing: MPFG runs dependent on available computing at ORNL Titan (GPU), NSF TACC (MIC), and Gaea-T3 (GPU).

Delivery of GPU and MIC chips from vendors.

Development of GFS physics package.

Risks

Computing resources are limited: An estimated 1 million node hours / year for ESRL & HIWPP on Titan will permit just 10-20 runs to be made in FY2014 at 3.5 km resolution.

Model development is unpredictable: The pace in which NIM and other non-hydrostatic models are developed will limit our ability to adapt to and optimize for MPFG in the timeframes we show (see Milestones).

OpenACC and OpenMP compilers are not ready: The F2C-ACC compiler is adequate, but further development may be needed if the openACC compilers are not ready. Alternatively, code changes and adaptions may be necessary to work around limitations in both compilers.

Scheduling
See above.

Budget
Detailed budgets provided under separate cover.

3.2.4 Non-Hydrostatic Icosahedral Model (NIM)

Task Lead: Jin Lee, ESRL/GSD

Introduction
The aim of this task is to develop a global non-hydrostatic modeling system capable of explicitly simulating convective clouds in order to improve medium-range weather forecasts, in particular, for high-impact weather events. ESRL's newly developed Non-hydrostatic Icosahedral Model, NIM, is designed to run globally at resolutions of 4 km or better to improve small-scale weather forecasts including high-impact weather predictions. NIM is a multi-scale non-hydrostatic model that allows explicit convection to interact with large-scale dynamics globally without limitations imposed by artificial lateral boundaries. Thus, NIM can potentially produce longer-lead and better high-impact weather prediction (HIWP) than current non-hydrostatic limited area models, which have demonstrated encouraging HIWP in recent years.

Outputs & Deliverables
To accomplish HIWPP task, a modeling system that can produce timely 10-day forecasts at 3-3.5-km global resolution to meet operation requirements, we will focus our model development on three areas which are (i) the 3-D finite-volume non-hydrostatic dynamical core (dycore), (ii) multi-scale physical packages suitable for multi-scales dycore, (iii) a modeling system running efficiently and scaled well on Massively Parallel Fine Grain computers.

NIM is a non-hydrostatic global model whose dycore is in flux form on height coordinate. NIM's governing equations are discretized with the three-dimensional finite-volume numeric formulated on the quasi-uniform icosahedral grid which is suitable for finite-volume numeric. Also, both the dynamics and physics can be more accurately formulated on the globally near uniform grid.

Two physical packages, GFS and GRIMS, are currently implemented and tested in NIM modeling system. GFS (Global Forecast System) physics operational version at NCEP will be used to benchmark 30km resolution NIM real data runs. The GRIMS (Global and Regional Integrated Model System) physics package developed by Professor Hong at Yonsei University is a multi-scale physics package. We plan to implement and test Weather Research and Forecasting (WRF) physics packages and study NIM sub-10km resolution retro runs for HIWPP.

NIM modeling system has been implemented to run efficiently on a single CPU, GPU and MIC processors as well and scale very well to thousands of compute nodes.

Quality Criteria

NIM dycore should produce similar idealized test cases for DCMIP case 2 and case 4 as those from other non-hydrostatic models.

NIM dycore and physical packages should generate realistic mid-latitudes jet streams and tropical easterlies in aqua-planet simulations for various physical packages with systematically increased model resolutions.

NIM modeling systems should run sub-10km resolutions efficiently and generate realistic mesoscale weather such as orographic precipitation.

Resources

All of NIM modelers including a new hire will work concurrently on HIWPP and NIM tasks. A new-hire modeler will initialize and configure NIM to run, diagnose, and verify various idealized test cases as well as retro-runs. WRF physics will be implemented into NIM modeling system. NIM group will collaborate with advanced computing group led by Mark Govett to configure NIM to run on MPP Fine Grain computers such as NVIDIA GPU and MIC architectures. To run NIM at ultra-high resolutions, it will require large computing resources.

Management

Dr. Jin Lee, HIWPP NIM task lead, will manage HIWPP task. The management includes careful planning HIWPP milestones, schedules and resources. Dr. Jin Lee will collaborate with HIWPP/non-hydrostatic modeling group on the requirements, scheduling and parameters of idealized test cases and retro-runs. Based on these requirements, Dr. Lee will seek a new hire and supervise the new hire to carry out HIWPP task. Dr. Lee will report the project progress to HIWPP project manager.

Milestones

See section 3.2 (all non-hydrostatic modeling groups have the same milestones).

Tolerances

NIM cannot meet HIWPP tasks if NIM budget to HWIPP for new hire is not approved.
NIM should produces good results for some (but may not be all) DCMIP test cases.
NIM should be able to run efficiently and scaled well in sub-10 km resolution real data retro runs.

Dependencies

NIM depends on the availability of Massively Parallel Fine Grain computers for sub-10km real data retro runs, as well as the Fine-grained parallelism work proposed by GSD advanced computing group led by Mark Govett.

Risks
NIM sub-10km real data retro runs cannot be completed without Massively Parallel Fine Grain computers.

Scheduling
NIM will spend the first year (2014 fiscal year) effort focusing on idealized test cases including DCMIP and APS, implementing WRF physics, as well as preparation for real data retro runs.

Budget
Detailed budgets provided under separate cover.

3.2.5 Model for Prediction Across Scales (MPAS)

Task Lead: William C. Skamarock (NCAR/NESL/MMM)

Introduction
The primary goal of the HIWPP project is to *accelerate the development of a global non-hydrostatic weather prediction system capable of running at ~3-km resolution in an operational forecast environment by late in this decade.* The non-hydrostatic atmospheric solver within the Model for Prediction Across Scales (MPAS-A) potentially could provide the atmospheric solver for this global non-hydrostatic weather prediction system. MPAS is comprised of geophysical fluid-flow solvers that use spherical centroidal Voronoi tesselations (SCVTs) to tile the globe and C-grid staggering of the prognostic variables. SCVTs (nominally hexagons) allow for both quasi-uniform tiling of the sphere using an icosahedral-mesh configuration as well as variable resolution tiling where the change in resolution is gradual and in which there are no hanging nodes (in contrast to models using traditional nesting approaches to enable refinement). Thus the non-hydrostatic atmospheric component of MPAS (MPAS-A) does not suffer from the pole problems arising from the use of a latitude-longitude mesh (in contrast to the NMMB and the future non-hydrostatic GFS), nor does it have computational or parasitic modes in the horizontally divergent motions present when using mesh staggerings other than the C-grid (in contrast to the NMMB, GFS, HIRAM, NEPTUNE and NIM). It also uses a horizontally explicit time integration scheme requiring only local communications (in contrast to the GFS), which is desirable to achieve good scaling in massively parallel computing applications. There are potential advantages for HIWPP models to have *the capability to run with non-uniform horizontal meshes and/or nests (to achieve higher resolution over certain areas such as the continental U.S. combined with the tropical western Atlantic).* It is also possible to add a more traditional regional nest capability (but using a polygonal grid) within the MPAS structure, if that would better meet NOAA operational requirements... The variable-resolution capabilities of MPAS-A eliminate the problems associated with traditional one-way and two-way nesting or models using other abrupt refinement techniques.

Given the potential advantages of the MPAS-A modeling system, NCAR will participate in the HI-WPP project through the further development and testing of MPAS-A as a candidate system for future operational use in NOAA. This work will involve assessing the performance of MPAS for a number of well-established idealized test cases, porting and tuning GFS physics packages in MPAS, assessing the performance of variable-resolution meshes in MPAS, running MPAS for an extended period of retrospective forecasts, and evaluating the overall MPAS performance in comparison to other candidate modeling systems.

NCAR's participation in this project is aimed at the development and testing of enhancements to the MPAS dynamics and physics that will provide improved model simulation/forecasting of high-impact weather events. NCAR will release and support these improvements as part of the MPAS community model, which will provide direct benefit to university researchers, specifically those focused on making more accurate forecasts of high-impact weather systems, such as Hurricane Sandy. In addition to the enhanced capabilities of MPAS for the research community, this project will also strengthen the interactions between the research and operational sectors of the Numerical Weather Prediction program in the U.S.

Outputs & Deliverables

The requested support and available computer resources will allow us to complete most of the following tasks as part of the HIWPP effort to test non-hydrostatic models, as specified in section 3.2. Outside computing resources may be necessary to complete the retrospective forecast test cases in year 2.

Quality Criteria

Success is defined by our ability to complete the tasks. With regard to tasks (1), (2), and (4), producing test results for the idealized test cases, and have these results be accepted as representing the capabilities of the model (in this case MPAS-A), as opposed to identifying problems with test case or model configuration, would constitute success. Correct solutions are available. Tasks (3) and (7) are science and software engineering development with well-defined expected outcomes. The other tests involve real-data forecast test, and success is defined primarily by the models ability to robustly produce forecast, and that these forecasts accurately represent the capabilities of the model.

Resources

NCAR Senior Scientists William Skamarock and Joseph Klemp will lead the NCAR work. Laura Fowler (Project Scientist) will lead the model physics development and evaluation. Additional software engineering and postdoctoral staff will be supported by project funds to conduct the model simulations and participate in the model evaluation.

Outside computational resources will be needed to support task (10) – the 12-month retrospective forecasts.

Management

NCAR Senior Scientists William Skamarock and Joseph Klemp will manage the project and will have the responsibility and authority to conduct the work within the context of NCAR policies. We anticipate frequent consultation with the lead of the Non-Hydrostatic Global Models working group, Jeff Whitaker.

Milestones

See section 3.2 (all non-hydrostatic modeling groups have the same milestones).

Tolerances

We do not anticipate any significant delays in performing our tasks, with the exception of finding computing resources to produce the 12-month retrospective forecasts. These resources need to be identified early in the 2-year work period.

Dependencies

There is only one explicit dependency in our tasks and their connections to others working on the HIWPP project – producing the new supercell test case that all the non-hydrostatic models will use. Other potential dependencies, such as the testing and evaluation of new scale-aware physics, are understood to depend on the development of these new physics components, and represent longer-term development efforts. We would like to have the GFS physics in MPAS-A for the retrospective forecasts, but these could be accomplished with the physics currently available in MPAS-A

Risks

The primary risk is having insufficient of computing resources, specifically for the 12-month retrospective forecasts.

Scheduling

The only specific dependencies are (1) the development of the new non-hydrostatic supercell test case that all the non-hydrostatic mode developers will use; (2) the desired porting of the GFS physics into MPAS to use in the 12-month retrospective forecasts test; (3) the computing resources to run the 12-month retrospective forecasts test.

Budget

Detailed budgets provided under separate cover.

3.2.6 Non-Hydrostatic Multi-scale Model (NMMB)

Task Lead: Zavisa Janjic (NCEP/EMC)

Introduction

The unified Non-hydrostatic Multi-scale Model on the B grid (NMMB) is being developed at NCEP as a part of the NOAA Environmental Modeling System (NEMS). The horizontal differencing employed in the model preserves important properties of differential operators and conserves a variety of basic and derived dynamical and quadratic quantities. Among these, conservation of energy and enstrophy improves the accuracy of nonlinear dynamics. The non-hydrostatic dynamics were formulated in such a way as to avoid over-specification. The global version is run on the latitude-longitude grid, and the regional version uses rotated latitude-longitude grid in order to reduce variation of the grid size. In the global limit, conservative polar boundary conditions are used, and the polar filter selectively slows down the wave components that would otherwise propagate faster in the zonal direction than the fastest wave propagating in the meridional direction. A variety of 1-way and 2-way nesting options is supported or being developed. The management of multiple static moving and telescoping nests is greatly simplified by the choice of the model grid. The physical package was developed from the standard WRF NMM's physics. Major updates have been introduced into the parameterizations of radiation, turbulence, and moist convection. A version of the entire physical package of NCEP's Global Forecasting System (GFS) is also available through NEMS. Some of its components can be used separately as well.

The regional version of the NMMB is run operationally as the main deterministic North American short-range forecasting model and in a number of other applications. The global NMMB has been run over the last few years experimentally in order to assess its capabilities and develop it further. Generally, the performance of the global NMMB in medium range weather forecasting has been comparable to that of other major medium range forecasting systems, and its computational efficiency satisfies and exceeds the current and projected operational requirements. At this stage, the top priorities are development of an indigenous multi-scale data assimilation procedure and a unified physics package (to the extent practicable) suitable for the full range of spatial and temporal scales on which the model will be applied.

The purpose of this task is to validate the performance of the NMMB on the global scales using a set of idealized and real data tests agreed upon by the participants of the subproject 3.2 dealing with Non-Hydrostatic Global Models. The tests are expected to provide a basis for meaningful inter-comparison of the participating global models at their current level of development. In order to do so, new or modified software systems for generating initial and boundary conditions, running the model and visualizing and assessing the results need to be developed for the experiments. The results of the experiments will be examined and compared with independent data used for control. In some cases, particularly with idealized tests with incomplete physics, model parameters may need to be tweaked for the particular problem at hand in order to achieve better agreement with control data. So, some of the experiments may need to be rerun, possibly many times. The planned activities are fully compatible with the concept, and follow the ideas of the subproject Non-Hydrostatic Global Models within which the task resides.

Outputs & Deliverables

EMC will reach an agreement with other participants of the subproject 3.2 about a standard test suite including no less than three of the idealized DC MIP tests. The analytic solutions will be used for control if available. If not, as will be agreed with other participants, independent well-converged numerical solutions obtained by groups that are not participating in the current sub-project will be used for control.

EMC will recruit and train scientific personnel for work with the NMMB within the NCEP's NEMS infrastructure. Software will be developed and thoroughly tested for specification of initial and boundary conditions for the test runs. Also, necessary interfaces with the existing software packages will be prepared for visualization, assessment and presentation of the results.

The idealized DC MIP tests will be run first, and the results will be evaluated by comparison with the control solutions. The results will be made available for comparison with the results obtained by other subproject participants.

EMC will reach an agreement with other participants of the project about a suite of real data tests on different temporal and spatial scales, as well as on the choice of independent initial and boundary conditions and verification suit for use in the tests. Software will be developed for conversion of the initial and boundary conditions, visualization and computation of scores on the NMMB grids. The input data, run scripts and other infrastructure will be prepared for extended forecasts over at least 1 year. A unified multi-scale model physics suitable for all spatial and temporal scales will be sought.

A 1-year of extended retro runs using reasonably high resolution will be carried out. The runs will be supervised, and care will be taken of the maintenance of the run stream. The results will be evaluated using agreed upon verification metrics and software. The results will be made available for comparison with the results obtained by other subproject participants.

A 3 km resolution global NMMB will be set-up. Preliminary tests will be carried out to assess the robustness of the model and computer resources required. If technically possible, 3 km global retro runs will be carried out as agreed upon. The results will be evaluated using agreed upon verification metrics and software and the verification results will be made available for comparison with the results obtained by other subproject participants.

Quality Criteria

In severe tests the software used must not show unexplained behavior or any indication of bugs. The test results should agree qualitatively with control data. In idealized tests it is usually possible to achieve very good results provided sufficient time and effort is invested into tweaking and tuning parameters of the simplified atmospheric model used. To what extent this will be done will depend on the availability of human and computational resources.

Resources
The recruitment is under way, but not finished. Well-qualified personnel is sought in order to avoid increasing the burden on the federal resources, which are already overstretched.

Management
TBD. There will be decisions that will require authority beyond that of the task lead.

Milestones

See section 3.2 (all non-hydrostatic modeling groups have the same milestones).

Tolerances
If the work falls behind for more than one quarter, raise the alarm. If the work falls behind more than two quarters, consider redesigning the task.

Dependencies
This task requires coordination in defining common goals and procedures within the subproject. Once the agreement is reached, further work on each task becomes rather independent.

Risks
It is uncertain at this time whether sufficiently competent personnel can be hired at such a short notice, and for such a short period of time.

The 3-km global runs will require substantial amount of computational resources. For example, one day of simulated time may take hours of wall clock time on 10000-20000 cores on a machine like Zeus. Will that many processors be available for hours, and will that have an impact on reliability of a machine like Zeus?

Storage for extended retro runs may not be available.

Scheduling
Please see the section *Milestones* above. Please note that in contrast to other participating groups on the subproject, no DC MIP tests have been carried out with the NMMB so far. This means that some catching up will have to be done with the NMMB, which may cause somewhat delayed delivery of some intermediate results compared to other groups.

Budget
Detailed budgets provided under separate cover.

3.2.7 High-Resolution Atmospheric Model (HiRAM)

Task lead: Shian-Jiann Lin (NOAA/GFDL)

Introduction

The goals of this task are to, a) further develop the GFDL global non-hydrostatic Finite-Volume dynamical core on the cubed-sphere (known as GFDL FV3), including various algorithm improvements and code optimization, b) perform idealized tests including, but not limited to, DCMIP test cases for model inter-comparisons, c) implement and improve cloud micro-physics suitable for cloud-resolving resolutions, and d) perform prediction experiments for high-impact weather events (e.g., hurricanes and super-cell thunderstorms) from days to months with comprehensive model physics (including land model) at the computationally affordable resolutions (from 3 km to 25 km). The results from this task will be shared and compared with other models from HIWPP to evaluate its suitability for potential transfer of the model or its components (mainly the non-hydrostatic dynamical core) to NCEP for operational consideration.

Outputs & Deliverables

- We will carry out the selected numerical experiments for inter-comparisons.
- We will make model outputs available to all participants of HIWPP.
- We will make the global non-hydrostatic dynamical core available to NCEP for research and/or operation considerations.

Quality Criteria

For the idealized tests and 10-day hindcasts, there are established methodologies to evaluate the quality of the results. For the 100-day “nature runs”, one can judge the quality of the simulations by the statistics of the simulated weather events (mid-latitude cyclones, hurricanes/typhoons, and, if resolution is near cloud-resolving, thunderstorms).

Resources

Human resources: For a 2-year (and up to 4-year) period, a visiting scientist and a software engineer/visualization expert to carry out the experiments and help analyze the results.

Computational resources: For the ultra-high resolution cloud-permitting simulations, substantial computing resources (from “Zeus” or similar platforms) will be needed.

Management

The task lead, S.-J. Lin, will manage the project, including hiring of new personnel via Princeton University. Dr. Lin will be responsible for the deliverables.

Milestones

See section 3.2 (all non-hydrostatic modeling groups have the same milestones).

Tolerances

The hiring of new personnel to assist this project will take about 3 months after the receipt of the funding.

Dependencies

The model-to-model inter-comparison can only be done after all modeling groups have performed the same tests. Performing 10-day hindcasts may depend on the availability of suitable NCEP initial conditions.

Risks

Scientists at GFDL have been developing and running in production mode with the global non-hydrostatic models during the past 10 years. With the resources made possible by HIWPP, we are confident we can make tremendous progress towards the prediction of severe weather events using higher resolution configurations of the model on synoptic to seasonal time scales. The only foreseeable threat to the success of this task is the lack of super-computing resources.

Scheduling

See milestones.

Budget

Detailed budgets provided under separate cover.

3.2.8 Navy Non-Hydrostatic Prediction System (NEPTUNE)

Task Lead: James Doyle (NRL)
Task Budget: NRL Funds

Introduction

This project will accelerate the development, testing, and evaluation of a non-hydrostatic weather and climate prediction model currently being led by the Naval Research Laboratory (NRL) and Naval Postgraduate School (NPS), and in collaboration with multiple institutions including other laboratories and academia. This new generation dynamical core and model will allow us to achieve convective-permitting resolutions on the sphere through the use of an accurate and highly-scalable dynamical core.

The Navy Non-hydrostatic Prediction System is based on the spectral element/discontinuous Galerkin dynamical core, the Non-hydrostatic Unified Model for the Atmosphere (NUMA). The discretization is performed on hexahedral elements (rectangular footprint). Since the spatial derivatives are computed analytically, there is no need for spatial staggering of prognostic variables and they all reside on the same nodal points. The conservation properties are accurate to the machine round off. The dynamical core is fully compressible and non-hydrostatic. The model forecasts can be performed either on the globe while utilizing the cubed-sphere, icosahedral grid, or over a limited area. Local mesh refinement has been implemented and tested. We are in the process of developing and testing an adaptive mesh refinement (AMR) capability. The model supports different time integration schemes, from fully explicit (leapfrog, Runge-Kutta), to semi-implicit. The semi-implicit correction can be applied in all three dimensions or in the vertical only. This flexible and highly scalable dynamical core can address a number of the HIWPP goals.

Outputs & Deliverables

We propose to perform idealized and real-data simulations in careful coordination with the HIWPP team. We will provide model output, model diagnostics, computational performance statistics, and participate in the careful evaluation of the HIWPP non-hydrostatic modeling systems.

The first phase of tests will consist of idealized tests that isolate the performance of the dynamical core, NUMA, with simplified physics. The computational efficiency and scalability will be documented. We will run tests with mesh refinement to achieve local resolution enhancement in areas of meteorological interest.

In the second phase of tests, a number of retrospective 7-day forecasts will be conducted at hydrostatic scales (with horizontal resolutions of 15-30 km). The model physics will be based on the Navy high-resolution physics suite, however we will consider testing the GFS suite of physics as well, contingent on adequate resources.

Our goal is to develop, test, and evaluate a non-hydrostatic global numerical weather prediction (NWP) system that is capable of predictions at convective-permitting resolutions. We anticipate the system should be high-scalable and optimized for emerging computing architectures.

Milestones

See section 3.2 (all non-hydrostatic modeling groups have the same milestones).

Quality Criteria

We will evaluate the results from the Navy Non-hydrostatic Prediction System using known solutions or expected results based on accepted model results in the literature for the idealized tests carried out in phase 1. In phase 2, the retrospective tests will be evaluated using analyses from data assimilation systems (e.g., NCEP GFS or Navy NAVGEM), and observations including radiosondes and satellite datasets. Success will be defined based on a scorecard of metrics from the HIWPP group, as well as the Navy specific metrics. We anticipate that the participating HIWPP non-hydrostatic models will be carefully compared and evaluated including the model state fields, as well as diagnosed quantities such as kinetic energy and mass budgets.

Computational efficiency or scaling results will be evaluated for several computational architectures. We will utilize both Navy and NOAA computational resources to document the efficiency for both strong and weak scaling examples. A linear scaling relationship is metric that can be used to evaluate the computational efficiency. Other well-established computational efficiency metrics will be used to evaluate the dynamical core and modeling system.

Resources

We will leverage two existing Navy projects related to the Navy Next-Generation Modeling System for this effort. These projects will include milestones that are closely coordinated with the HIWPP non-hydrostatic project. Investigators at NRL who are anticipated to contribute to this project include:

Dr. James Doyle
Dr. Sasa Gabersek
Dr. Kevin Viner
Dr. Alex Reinecke

Computational resources will consist of platforms within DoD and NOAA. We will utilize computational platforms at the Navy DoD Supercomputing Resource Center (Navy DSRC), which is a leading provider of high performance computing services and support to the DoD scientists and engineers. It is one of five supercomputing centers established under the auspices of the DoD High Performance Computing Modernization Program (HPCMP). The Navy DSRC leverages high performance computers and a wealth of knowledge to greatly improve the computational research environment for DoD researchers. The center also provides leadership for HPCMP-wide functions including remote petascale data storage, enterprise systems monitoring, and remote system and database administration. The Navy DSRC platforms include two IBM iDataPlex systems, Haise and Kilrain (435 TFLOPS each), and a Remote Mass Storage Server (RMSS) system (composed of a single Oracle T4-4 server named Newton). We will also utilize the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, which is the premier research and development laboratory complex for the Corps of Engineers. We will primarily utilize the Cray XE6, Garnet, which is a 1.5 PFLOPS platform and consists of 4716 compute nodes (32 cores per node).

To address our task plan, we will likely need to obtain additional computational resources from the DoD HPCMP, as well as NOAA computational platforms.

Management

The project management team as outlined in the HIWPP Work Breakdown Structure is described as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.2.8 POC, Doyle	3.2, 3.5 & Project Mgr.	Document
Status Reports	3.2.8 POC, Doyle	3.2, 3.5 & Project Mgr.	Document, Status Report

			Template
Project Advisory Group	3.2.8 POC, Doyle / 3.2 Test Mgr., Project Mgr.	NRL Superintendent	Meeting
Technical Team Meetings	3.2.8 POC, Doyle	Technical Team	Project Management Plan
Sponsor Meetings	Project Manager, 3.2 Test Mgr. & 3.2.8 POC, Doyle	NOAA/OAR HIWPP, Navy Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.2.8 POC, Doyle, 3.2 Test Mgr., Project Mgr.	Project Advisory Group, NRL Superintendent, Users, NOAA HIWPP, Navy Management	Presentation and Discussion

Project Management Guide

Responsibilities of the Non-hydrostatic Navy Model POC/Technical Lead:

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team
- Provide requirements understanding and guidance to the development team
- Work closely with different laboratories on idealized and retrospective non-hydrostatic experimental forecasts
- With 3.5.3 POC, coordinate initial implementation of existing verification software and planning for unification of software and addition of new capabilities
- Establish communication plan and schedule with other HIWPP POCs
- Develop tasking, schedule and budget for all aspects of the Navy non-hydrostatic global model effort in coordination with all groups involved in development
- Coordinate with other HIWPP project areas to leverage meetings, demonstrations and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting and critical develop monitoring and guidance

Tolerances

We will leverage existing Navy projects to support this effort. Additionally, sufficient computational resources may be an issue. Greater tolerances may be needed for this project relative to others given we are leveraging non-NOAA resources. We may not be able to run for a full year of tests as part of Phase 2, for example.

Fault	Tolerance	Impact
Idealized simulation suite capability	No more than 1 month after scheduled date of Sept. 2014	Initial capability for evaluation of idealized non-hydrostatic expt. runs
Hydrostatic-scale retrospective capability	No more than 2 months after scheduled date of June 2015	Capability critical for evaluation and decision-making on non-hydrostatic expt. runs on hydrostatic scales.
Mature verification capability	Unable to complete retrospective tests in timely manner	Detailed evaluation and testing process for non-hydrostatic models takes longer than expected

Dependencies

We will leverage two existing Navy projects to support this effort. Additionally, we will leverage some Navy computational resources. Other dependencies include coordination tasks related to the inter-comparison of the various HIWPP non-hydrostatic models. We will also have a close coordination with the Naval Postgraduate School (NPS) and Professor Frank Giraldo's group, who have spearheaded the development of the NUMA dynamical core that we will be using.

Risks

The risks that can impact this project include those of a i) technological, ii) funding, and iii) computational nature. We are still in the process of developing the Navy's next-generation non-hydrostatic modeling system. Although the system is maturing rapidly, we anticipate there still are technical hurdles related to the modeling system that need to be addressed. There is a small risk that some of these hurdles may require more time than anticipated to address, slowing the progress on the milestones. From a funding perspective, we are leveraging resources outside of this HIWPP project, and some risk is inherent. From a computational perspective, resources are limited and our progress may be slowed by inadequate computational resources. As an example, we may not be able to run for a full year of tests as part of Phase 2 with limited human or computational resources.

Scheduling

We anticipate that the Phase 1 idealized tests will require approximately 9 months to one year of effort and should be completed by the end of FY14. The Phase 2 milestone will begin in FY14 and results will become available in FY15 with the final tests available by the end of FY15.

Budget

No HIWPP funding is proposed for this project, although if resources were to become available, we would be able to accelerate our effort and more fully participate in the HIWPP. We will leverage existing projects within the Navy supported by ONR and PMW-120.

3.3 Moving Hurricane Nest

High-resolution Moving Nested Multi-Scale HWRF Model in NMMB/NEMS Framework for Improved Hurricane Predictions

This subproject has a single task.

3.3.1 Moving Hurricane Nest

Task Leads: S. Gopalakrishnan (AOML) and Vijay Tallapragada (NCEP)

Introduction

More than 80-90% of the deaths due to Tropical Cyclones are caused by fresh water flooding and storm surge. Current high-resolution operational mesoscale models for hurricanes, such as the Hurricane Weather Research and Forecasting (HWRF) system, are more focused on the wind intensity predictions and do not address land-fall related issue. Land and tropical cyclone interactions are complex to model and require a multi scale modeling system. The aim of this task is to create a multi-scale hurricane prediction system working at 3 km resolution providing improved predictions of land-falling tropical cyclones.

AOML and NCEP along with other HIWPP partners will participate in this project to accomplish or accelerate the development of a fully two-way interactive moving nested, multi scale, non-hydrostatic modeling system using NMMB in the NEMS framework. *This effort will greatly enhance the development of NOAA's future numerical guidance strategy necessary to improve our understanding and prediction of hurricanes and their impacts in order to save lives. A major goal of this proposed effort is to improve our understanding of the processes that influence the impacts from these devastating storms through better representation of the physical processes within the HWRF/NMMB and NEMS frameworks*. The HWRF nests will be designed to operate at about 3 km resolution desired for capturing tropical cyclone inner core process and interactions with the large-scale environment, critical for improving not only track and intensity predictions but also rainfall and size predictions.

The earlier collaborative effort between AOML and NCEP resulted in the creation of the high resolution operational HWRF that has demonstrated exceptional skills in track and intensity forecasts. However, tropical cyclones such as Irene (2011), Isaac (2012) and Sandy (2012) have all illustrated the importance of providing more accurate rainfall and size (for storm surge) predictions. The current operational HWRF configuration is storm centric and single nested not ideal for representing multi-scale interactions or for post landfall applications, and is greatly limited in extending forecast lead times beyond 5 days. Key for improving near land fall (size) and post-landfall applications (rainfall) and for extending forecast lead times beyond 5 days lies in the creation of a basin scale model (eventually covering the entire globe) with multiple moving nests at 1-3 km resolution covering all the storms in the basin. Indeed, AOML working with NCEP has further advanced the HWRF system in terms of producing a regional basin-scale hurricane prediction system. For the first time, an experimental version of the Basin Scale HWRF capable of providing finer resolution down to 3 km to any number of storms in a domain encompassing the Atlantic and the East Pacific basins is run real time during the 2013 hurricane season. Figure 4 illustrates multiple moving nests of 3 km resolution embedded in the basin-scale HWRF. The Basin-Scale HWRF with multiple moveable nests started showing promise. However, this configuration is neither scalable nor can be extended to a global framework.

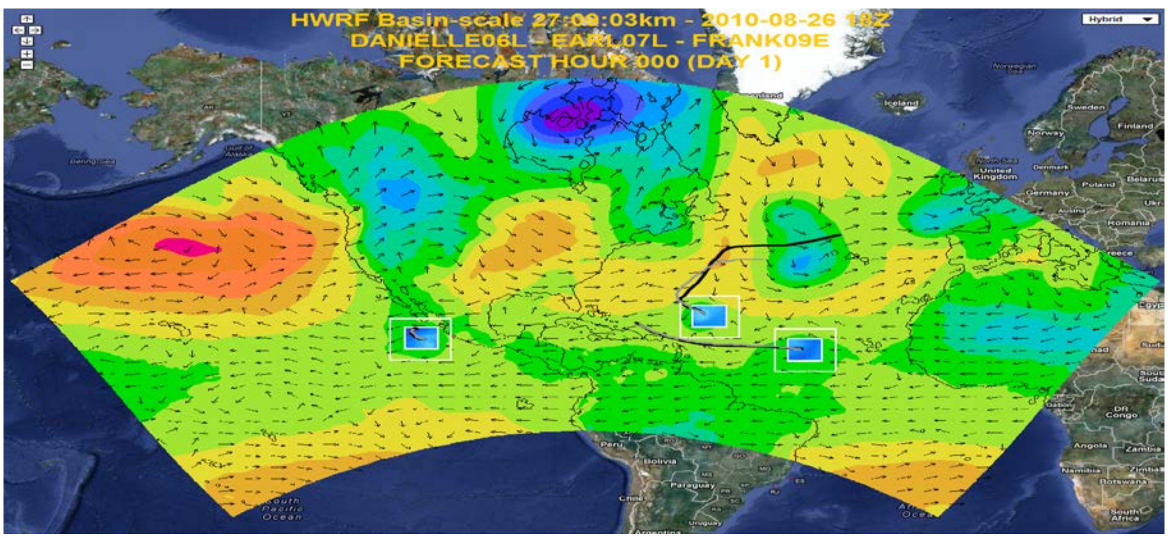

Figure 4 A working prototype basin-scale HWRF system with multiple moving nests. The parent HWRF domain is 27-km resolution, and the innermost nest is at 3-km, covering 3 tropical storms.

The NMMB within the NEMS framework is the only Global Non-Hydrostatic model sufficiently developed and capable of operating a moving nest at 3-km or higher resolution. Other Non-Hydrostatic models in this effort are either not geared towards the nesting approach (e.g., NIM, MPAS and HIRAM) or may not be available in a timely manner (within 2 years) to implement the high resolution, HWRF nesting technology and the associated hurricane initialization and physics packages. Implementation of all the three components is critical to advance our scientific goal of improved hurricane track, intensity and structure predictions with special emphasis on land falling storms (size and rainfall) and of extending forecasts beyond 5 days. The NMMB may be configured as a regional as well as a global model. In the regional mode, options to test HWRF in NMMB/NEMS framework with initial and boundary conditions from different hydrostatic and non-hydrostatic global models being developed in this HIWPP effort will be made available to other collaborators.

The success of HWRF in track, intensity and structure forecasting lies not only in its nesting capability but also in its physics package, part of which was advanced at AOML using hurricane core observations and the hurricane initialization technique that was developed at NCEP. All three hurricane-specific components from HWRF (nesting, physics and vortex initialization) will be transitioned to the NMMB/NEMS framework before testing the model for providing improved tropical cyclone track and intensity forecast guidance in a multi-scale environment. Systematic testing and evaluation of each of the HWRF components in the NMMB/NEMS framework is critical for demonstrating the benefits of high-resolution nests within a non-hydrostatic multi-scale model. In addition, as we move towards global non-hydrostatic models for hurricanes, a greater focus is required for an improved land surface component and multi-scale physics. Data assimilation and ocean coupling are equally important for operational tropical cyclone forecast needs, however, those aspects will be leveraged from other supported efforts (e.g., HFIP, NOPP, other Sandy Supplemental), and projects geared towards NMMB development at NCEP.

Motivation

In order to forecast Tropical Cyclone structure, size and intensity changes with fidelity, the inner core structure of these storms must be resolved at 1-3 km horizontal grid spacing. Although global non-hydrostatic models are envisioned to run at higher resolutions by the end of this decade, it remains to be seen if these models can routinely operate at a uniform, 1-3 km resolution, providing reliable forecasts four times a day. Grid nesting appears to provide a reliable and practical approach for the hurricane-forecasting problem both at the regional as well as the global scale.

NCEP Operational HWRF is now used for guidance in all basins in the Northern Hemisphere with proven value for track, intensity and structure predictions through consistently improved performance. However, limitations of operational HWRF include storm centric configuration and single telescopic nests. Focus areas for next generation hurricane model development includes capturing multi-scale interactions within a fixed domain with multiple moveable nests (e.g. Hurricane Sandy, Hurricanes Igor and Julia); fixed outer domains also have advantages for advancing DA techniques and for downstream landfall and post-landfall applications.

NMMB is a truly multi-scale model that can be configured in global as well as the regional model. Also, NMMB/NEMS is the adopted pathway for operational regional scale applications at NCEP. Extending that for multi-scale hurricane forecast applications should provide a seamless pathway towards next generation operations. Placing HWRF capability into NMMB-NEMS will take advantage of the global NMMB developments supported by HFIP including code optimization, application to accelerators, NEMS coupling infrastructure, etc. The adopted pathway will result in seamless transitions from HWRF (NMM-E) dynamics to NMMB/NEMS framework. The regional configuration may be used by any of the other hydrostatic or non-hydrostatic global models participating in this effort.

This sub-project will leverage on the NOAA's success with the HWRF system and support from HFIP; and accelerate progress towards creating high resolution, next generation multi-scale hurricane model for comprehensive hurricane forecast solutions *with an emphasis on improved rainfall and size predictions for land falling storms.* A schematic showing the overall goals and timelines of this sub-project are presented in Figure 5.

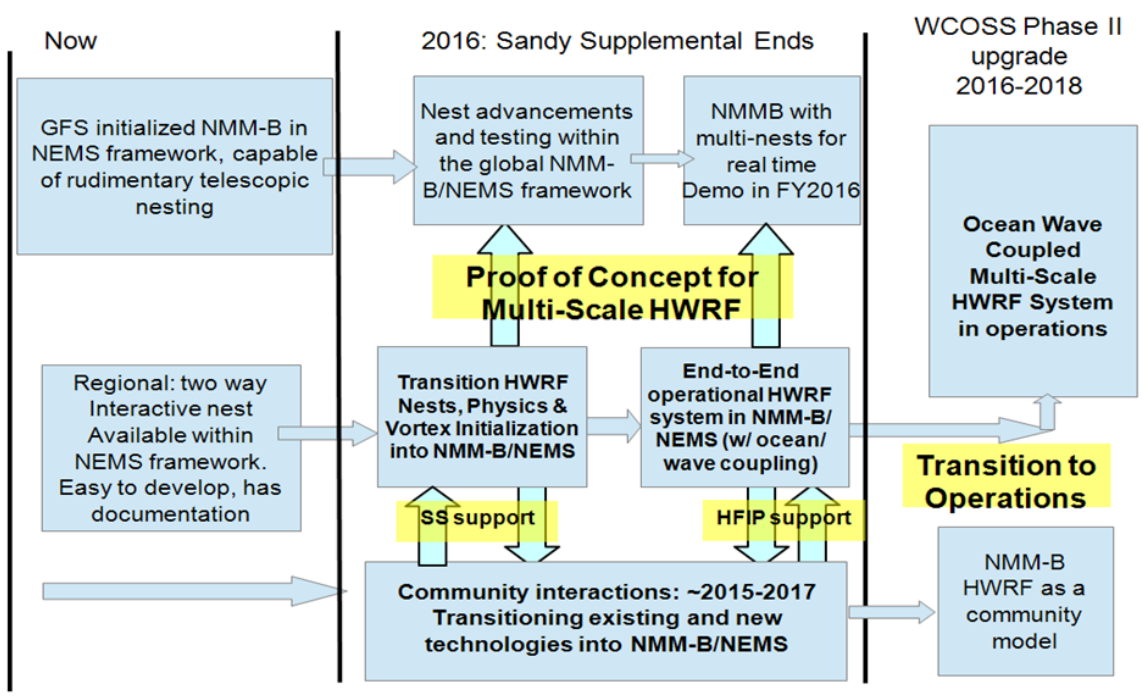

Figure 5 Schematic describing the planned development of multi-nested NMMB/NEMS for hurricane applications. The HIWPP subproject will leverage HFIP support in accelerating progress towards the implementation of a multi-scale HWRF system at NCEP by 2016-2018.

Outputs & Deliverables

End goals:

- Create the next generation, non-hydrostatic, HWRF system capable of capturing better, land-TC multi-scale interactions, critical for landfall applications. This modeling system will have a very high potential to transition to operations
- Options to test HWRF nests in NMMB/NEMS framework with initial and boundary conditions from different hydrostatic and non-hydrostatic global models being developed in this HIWPP effort will be made available to other collaborators

- Proof of concept of Global tropical cyclone model with multiple moveable nests placed around all tropical systems in the world

Available:
- NMMB/NEMS global model configuration (currently runs without nesting)
- NMMB regional model configuration with moving nest techniques adopted from an earlier version of HWRF system
- 2013 Basin Scale HWRF (extended version of 2013 HWRF with multiple moving nests)

The plan:
- Develop idealized capability within the NMMB/NEMS framework and establish a baseline hurricane capability
- Mimic 2013 HWRF configuration in NMMB/NEMS framework (includes transitioning physics, vortex initialization and advanced nesting techniques from FY13 HWRF)
- Demonstrate the feasibility of running 3 km, multi-nested, regional and global scale HWRF with a focus on land falling TCs

HRD/AOML's role will be in the following areas:
- Developing idealized capability for hurricanes in NMMB
- Adopting multi-nest approach from basin-scale HWRF to NMMB
- Testing various configurations (physics, tuning different parameters, etc.)
- Conducting model diagnostics and evaluation
- Documenting the progress and writing reports

EMC/NCEP's role will be in the following areas:
- Adopt HWRF two-way interactive nests and nest movement algorithm into NMMB/NEMS
- Implement HWRF physics into NMMB/NEMS
- Develop HWRF vortex initialization for NMMB and transition post-processing capabilities
- Provide training on NMMB/NEMS to new and existing scientists working on this project
- Conduct large-scale retrospective testing and evaluation and real-time demo
- Coordinate with HFIP supported tasks and prepare for implementation of multi-scale HWRF modeling in NMMB/NEMS framework into operations

Quality Criteria

Success of this project is determined through demonstration of NMMB/NEMS forecast skills that match or exceed current operational HWRF. Rainfall and size verifications will also be evaluated, especially for land-falling storms. Development of high-resolution multi-nested hurricane model within a global non-hydrostatic modeling framework for improved tropical cyclone predictions is the final goal of this sub-project.

Resources

The workforce for this sub-project will include 4-5 new hires using HIWPP funds. Experience and expertise of HWRF team members at NCEP and AOML and NMMB developers at NCEP will be utilized in accelerating the progress of the proposed tasks. Initial model development and testing activities will take place on NOAA R&D computational resources allocated for NCEP and AOML on Jet and Zeus for hurricane modeling activities (supported by HFIP and NCEP). We anticipate use of 1 million core hours per month on Jet and Zeus for the first year of the project followed by 2 million core hours per month for the second year. Data storage needs include disk space and tape storage of about 100 TB and 500 TB for the first year, and 200 TB and 1 PB for the second year respectively. Forecast products and datasets will be disseminated through NEIS as well as AOML/NCEP web servers. Near-real time forecast demonstration activities would require transfer of NCEP operational GFS analysis and forecast data sets (or other non-hydrostatic global models supported by HIWPP) to Jet/Zeus.

Management

Both the team leaders of the sub-project are leads of hurricane modeling teams in their respective organizations and enjoy the freedom of making decisions that best benefits NOAA. Nevertheless, both the team leaders work closely with their respective lab directors and get them updated on progress of each of the tasks at least once or twice a week. The management is very supportive of this project. The AOML Director manages the funding for this task, but both team leads have the flexibility in terms of choosing the hires and making travel plans for this project. The leads will consult their directors and work between the labs frequently during this project.

Milestones

Second Quarter of FY14:

- Feb 2014: Complete initial training on NMMB/NEMS for staff, procure computational resources, set up development branch within the EMC subversion and identify/prioritize HWRF components for transition to NMMB/NEMS.

Third Quarter of FY14:

- June 2014: Transition NMMB to a research model configuration. Evaluate existing capabilities of NMMB and start to implement HWRF vortex initialization scheme in NMMB. Start implementing HWRF nest motion algorithm into NMMB. **Transition to jet ongoing.**

Fourth Quarter of FY14:

- September 2014: Configure, test and evaluate NMMB for hurricane forecast applications: mimic existing operational HWRF configuration, develop idealized/semi-idealized capability for hurricane simulations in NMMB, implement important HWRF physics schemes in NMMB and develop HWRF vortex initialization for NMMB.

First Quarter of FY15:
- December 2014: Complete implementation of the appropriate physics suite from HWRF to NMMB, transition HWRF nest upgrades to NMMB, tune physics and dynamics for hurricane applications.

Second Quarter of FY15:
- Complete implementation of HWRF vortex initialization. Confirm effectiveness of two-way nesting, physics and vortex initialization for NMMB using selected case studies.
- Conduct preliminary tests on NMMB nest testing with HWRF physics and vortex initialization for tropical cyclone case studies.

Third Quarter of FY15:
- Report on NMMB nest testing with HWRF physics and vortex initialization for tropical cyclone case studies.
- April 2015: Transition multiple telescopic two-way nesting capabilities into the multi-scale NMMB/NEMS framework. Test different configurations/resolutions for the multi-nested NMMB.
- June 2015: Fine tune physics and vortex initialization for hurricane applications, and proof of concept for NMMB/NEMS multi-scale non-hydrostatic model with multiple moveable nests.

Fourth Quarter of FY15:
- September 2015: Perform large scale retrospective tests using the hurricane application NMMB, and tune physics/vortex initialization again if needed. Confirm the effectiveness of the implemented nest motion algorithm of HWRF system into NMMB frame work.

First Quarter of FY16:
- December 2015: Evaluation and verification of storm structure and rainfall forecasts from NMMB hurricane model runs for landfalling storms.

Second Quarter of FY16:
- Produce a report on the performance of the NMMB/NEMS for hurricane track, intensity, structure and rainfall predictions based on retrospective runs.

A demonstration of the multi-nested NMMB/NEMS model for hurricane forecast applications including rainfall and storm structure, and proof of concept of the multi-scale non-hydrostatic hurricane model running at 3 km resolution will be completed during the next hurricane season.

Tolerances

The Hurricane Nests sub-project assumes smooth implementation of HWRF components into the NMMB in the NEMS framework for comprehensive testing and evaluation activities. There are a lot of check points put in place for the project leads to measure the progress, and inform their respective lab directors and HIWPP project management of any potential slippage and re-direction required to accomplish the goals.

Dependencies

Most of the proposed tasks for this sub-project are stand-alone and will independently be carried out by the NCEP/AOML personnel associated with this project. Demonstration of hurricane forecast performance (and scientific value) of NMMB is dependent on timely implementation of HWRF nests, physics, and vortex initialization components into the NMMB/NEMS framework, leverage from HFIP supported activities in terms of ocean coupling, post-processing, multi-season T&E and availability of computing resources. Code optimization and speed-up for multiple moveable HWRF nests in NMMB/NEMS will depend on readiness of GPU/MIC applications for global NMMB.

Risks

As with any other sub-project within HIWPP, the HWRF Nests sub-project will also suffer if there are no adequate computational resources. Additional risks could come from lack of flexibility of NEMS framework in porting various physics packages and ESMF coupler functionalities, code management issues, and lack of timely availability of global model datasets for conducting the T&E. Availability of funds by November 2013 and timely hiring is very critical for this effort.

Schedule

See above.

Budget

Detailed budgets provided under separate cover.

3.4 National Multi-Model Ensemble (NMME) Expansion

This subproject has a single task.

3.4.1 NMME Expansion

Task Lead(s): Jin Huang (NCEP Climate Test Bed)

Introduction

The goal of the NMME (National Multi-Model Ensemble) expansion task is to evaluate and establish the prediction capabilities of high-impact weather extremes out to several months by leveraging and enhancing the existing NMME system and data.

The NMME is aimed at developing a prediction system consisting of various US climate models to improve operational forecast skill on intraseasonal to interannual (ISI) time scales and to provide real-time forecasts and research data to the research and user communities. The marriage between the research and operational communities is a unique focal point of the project, and is proving to be a key driver of new understanding of ISI predictability and forecast skill. The NMME project is currently funded by NOAA, DOE, NASA and NSF. The daily and monthly NMME reforecast data will be archived at NCAR and available to the public.

While this activity will not be the primary focus of the HIWPP project, the additional funding will leverage the NMME project to ensure that HIWPP encompasses a seamless suite of extreme weather and natural hazards prediction tools. The NMME expansion in HIWPP project will enhance the NMME reforecast data with increased number of output variables and higher spatial/temporal intervals, as well as support additional NOAA scientists to evaluate forecast capabilities and predictability of ISI changes in the statistics of high-impact weather events, such as, hurricanes, tornadoes, heat waves, cold spells and major winter storms using existing NMME models. For example, this project will address whether the probability of a hurricane or a major flood event is increased over the next 30-days or if we can predict these changes in probability a few seasons in advance. This intraseasonal to seasonal capability is essential as NOAA seeks to use the HIWPP project to develop a seamless suite of extreme weather and natural hazard forecasts and warnings. Moreover, the enhanced high-frequency NMME reforecast data will facilitate comparison of the existing NMME models and the new models under development in HIWPP. They will also increase the type of model outputs available to researchers and other customers and lay the groundwork for improving NMME-based high-impact weather prediction at sub-seasonal time scales. Together with the other subprojects in HIWPP, the NMME expansion project will ultimately improve NOAA's forecast capabilities for high-impact weather across weather and ISI time scales.

Outputs & Deliverables

Task 1: Evaluate NMME-based hurricane seasonal outlook

Since 2009, the NCEP Climate Prediction Center (CPC) has been utilizing the NCEP Climate Forecast System (CFS) in the T382 resolution as the primary tool for dynamic hurricane season prediction.

The task in HIWPPP is to incorporate the NMME prediction suite as part of forecast procedures for the Hurricane Seasonal Outlook (HSO) preparation. The deliverable of this task is an assessment report of predictive skill of tropical cyclones in the NMME models. The tropical cyclone activity in the NMME models over the hindcast periods will be analyzed at CPC in full detail—daily locations (leading to tracks), strengths, and basin-wide ACE (accumulated cyclone energy). Also evaluated will be the atmospheric and oceanic circulation features such as SST and vertical wind shear, which are considered the most relevant environmental conditions for tropical storm activity. The results will be analyzed in terms of climatology and interannual variability in the numbers of named tropical storms, hurricane and the ACE Index over all four northern hemisphere ocean basins, but the main emphasis will be on the Atlantic Basin. The initial evaluation procedures will be applied to the hindcast suites of April and July initial conditions to be applicable for the CPC HSO issued in May and its update in early August.

Task 2: Test real-time NMME-based hurricane season prediction system

The next step is to test a real-time hurricane season forecast system using the T382 CFS and NMME models after the evaluation phase (in Task 1) is complete. If two or more models in the NMME system exhibit value in capturing interannual variability of the tropical cyclone activities, the MME Atlantic tropical cyclone prediction system will be developed and tested in the second year of funding. The MME will be assembled using insights and lessons learned from previous multi-model consolidation studies regarding model bias correction, model weighting and determination of the forecast probability distribution.

Task 3: Assess severe weather environmental factors using NMME data

There is no current national capacity to provide skillful long-range severe weather outlooks. In response, a series of workshops were held to assess the current state of the science and to identify requirements to develop long-range severe weather outlook and attribution products that span the intraseasonal-to-seasonal timescales. Nascent efforts toward this goal are already underway and have demonstrated the potential for advancing our long-range prediction capabilities. These early efforts will be expanded in collaboration with scientists at the University of Miami. Indeed, one example of success in this regard is the Tippet et al (2012) study, which found using observed relationships between large-scale environmental parameters and tornado occurrence that the NCEP Climate Forecast System (CFS) demonstrated skill in predicting monthly tornado probability. Can this skill be enhanced using a larger suite of models and ensemble members from the NMME project?

In Task 3, a CPC scientist who has been leading the development of the White Paper on “Advancing the Nation’s capability to anticipate tornado and severe weather risk” will work with the U. Miami team who is currently funded by the NMME project to provide the basis for a more comprehensive model skill evaluation of factors critical to the long-range severe weather environment over the U.S. Chief among these are the El Nino Southern Oscillation (ENSO) phase transitions as captured by the Trans-Nino index (TNI), low frequency modes of North American low-level jet (NALLJ) variability, and thermodynamic and boundary condition fields important for supporting the severe weather environment (e.g., CAPE, helicity, soil moisture, etc.). A report will be produced on the analysis of these severe weather parameters in the reforecast datasets of all contributing NMME models to understand their skill in predicting the large-scale severe weather environments.

Task 4: Enhance the current NMME Phase-II data

The current NMME Phase-II project does not have the capability to archive daily or higher frequency data for all variables at all levels. To meet the requirements for evaluating and developing NMME-based high-impact weather outlooks and model diagnosis and comparison with other models developed and evaluated in the HIWPP project, the NMME expansion project plans to enhance the Phase-II data as follows:

1) Archive 6-hourly data for the following list of variables: Mean sea level pressure, Surface temperature (SST and land), Precipitation, Temperature at 2m, 850, 700, 500 and 200 mb, and Winds (both u and v) at 10m, 1000, 850, 700, 500 and 200 mb. These data will service broad research and the user community, but more specifically can be used to calculate critical high-impact weather related variables such as CAPE.
2) Archive 3-hourly surface data for Navy application research: 3-hr surface winds (to drive the Navy wave models), 3-hr surface currents (to look at ship routing), and 3-hr surface pressure (to look at surge)
3) Archive more daily data at more levels requested by other HIWPP subprojects. The details will be determined after discussions between the NMME team and the HIWPP partners, and will be specifically designed to meet focused research and development needs.

The NCAR data group will also work with HIWPP Test Program in terms of data extraction and visualization tools for other HIWPP subprojects.

Quality Criteria

The performance measure metric may be constructed based on skill scores of interannual variability of tropical cyclone activities over the Atlantic basin, such as the anomaly correlation score and the root-mean square error of the number of tropical cyclones with bias correction. The goodness criteria may be based on the minimum level of other tropical cyclone prediction tools currently available at CPC.

The project is considered a success if all four tasks are completed and all the milestones and real time contributions towards CPC's HSO and US Hazards Outlooks are accomplished by the end of FY2015.

Resources

- **Human**:
  - Tasks 1 and 2: Jae Schemm from NCEP/CPC and a contract support staff will carry out the activities. Jae is the leading developer of the current CPC hurricane seasonal outlooks.
  - Task 3: Scott Weaver from NCEP/CPC and a student from U. Miami (CIMAS) will carry out the task. Scott has led the development of a White Paper on

"Advancing the Nation's capability to anticipate tornado and severe weather risk". The U. Miami team is currently working on the NMME Phase-II project.
  - Task 4: Eric Nienhouse from NCAR will provide oversight on the data archive, data management, data curation and end user support. Eric will also coordinate with HIWPP Test Program on data extraction and visualization .

- **Hard Disks**:
  - Data storage and access of enhanced NMME data
  - Hard disks at NCEP to process data for Tasks 1, 2, and 3

Management
The NMME expansion project in HIWPP will be managed by Jin Huang, Director of NCEP Climate Test Bed (CTB). She will provide coordination between the NMME-HIWPP team and the HIWPP project managers regarding the development of the work plan, funding allocation/mechanisms and project progress. She will provide oversight and monitor progress of the four tasks in the NMME component of the HIWPP project.

Milestones
Fourth Quarter of FY14:
- July 2014: Complete the archive of the enhanced NMME data for public access

Second Quarter of FY15:
- January 2015: Complete evaluations of NMME-based hurricane seasonal outlook
- March 2015: Complete setup of the NMME-based hurricane seasonal outlook procedure

Third Quarter of FY15:
- April 2015: Test real-time NMME-based hurricane seasonal outlook
- Final completion of the archive of the enhanced NMME data for public access, delayed from FY14 due to slower transfer speeds than expected

Fourth Quarter of FY15:
- September 2015: Complete the evaluation of NMME-based severe weather environmental factors

Tolerances
Much of the project depends on the successful transfer of data from the forecast providers to the NCAR data server. One potential bottleneck that may require the reevaluation of the time is the data transfer rate and the speed with which the forecast provides can retrieve data from archive.

Dependencies
This project leverages the NMME Phase-II data, which are contributed by multiple modeling centers/groups including NCEP, NCAR, NASA, U. Miami, and Canada. Tasks 1 and 2 leverage NCEP/CPC activities in CFS-based hurricane seasonal

outlook. This activity leverages the computing and data storage resources of the various forecast providers. In addition, the U. Miami team makes extensive use of NOAA computing resources (GAEA) in the current funded NMME Phase-II project.

Risks

- Availability of NMME-Phase-II data. The current plan is to have the data in place by July 2014, along with the enhanced components. This timeline may be impacted by the commitment from each contributing modeling center.

Scheduling

See above.

Budget

Detailed budgets provided under separate cover.

3.5 Test Program

Workgroup Lead: Bonny Strong (ESRL/GSD & CIRA)

NB: *The Test Program Subproject section was drafted by Jebb Stewart (ESRL/GSD)*

There is a unique but missing "big data" niche that lies somewhere between a research environment and a fully operational system: a framework for model development that allows developers and data users alike to access, process, visualize and analyze large volumes of gridded earth system data; in particular for gridded high-resolution numerical weather model forecasts. Thus a key component of HIWPP will be the development of a capability for testing and evaluating the accuracy of global numerical weather prediction systems, and ultimately for running mature systems in near real-time. This research capability will complement the capabilities now present at the operational center by allowing for more extensive testing of new technologies and models that may be a large departure from the current operational system. It will also allow for more community involvement in the development, testing, and evaluation process.

Another key part of this facility will be a system to enable real-time access of global-scale and regionally subsetted model data to a diverse community of users. This system will build upon the prototype NOAA Earth Information system (NEIS) developing advanced dynamic visualization, and analytics in addition to on-demand dissemination of forecast data. Where possible, model products and visualization tools will be consistent with those used in existing programs, and new tools will be created with a goal of providing these products for review to related programs such as NUOPC.

ESRL, in consultation with EMC, will build upon the NEIS and create the test program architecture and methods to permit advanced users to access the experimental quasi-real-time model output and will develop capabilities for interactive visualization of model output, using existing structures that are readily available, when possible.

To assist model evaluation, the test program will develop and implement statistical tools to compare, quantify, and study the performance of the new prediction system relative to operational global prediction systems. This includes creating improved output of forecaster-oriented metrics and indices useful for medium and extended range timescales. Additional outputs will provide assessments of forecast uncertainty, particularly for medium and longer-range ensemble products. Regular verification of the ensemble guidance, both individual model components and the multi-model product will be made readily available. The verification will include standard metrics (anomaly correlations, RMS errors, error statistics currently computed by NWS, etc.) and ensemble verification of regular and high-impact forecasts (e.g., heavy precipitation, hurricane track and intensity).

3.5.1 Statistical Post-Processing

Task Lead: Isidora Jankov (ESRL/GSD & CIRA)

Introduction

Having a reliable and skillful forecast, especially in the case of high-impact weather events, such as hurricane Sandy, would facilitate better decision-making resulting in saving lives and minimizing property loss. For more accurate longer lead-time forecasts it is necessary to use global modeling systems. In recent years, ensemble-forecasting techniques have been increasingly used. Early into the ensemble-forecasting era, ensemble mean values were found to estimate the verifying state (usually large-scale circulations) better than the forecast from a single ensemble member. Ensembles also are advantageous because they supply probabilistic forecast information, which may be of more value to users than a single deterministic forecast. The ensemble dispersion gives an estimate of forecast uncertainty.

The main goal of this task is to statistically combine information from a mini-ensemble consisting of three deterministic, hydrostatic, high-resolution global models and coarser resolution global ensembles to produce the best estimate of surface temperature, wind, precipitation, and 500-mb anomaly correlation. The models of interest are ~ 13km, 15km, 20km deterministic runs from GFS, FIM and NAVGEM global models, respectively, and corresponding coarser resolution ensembles (10-20 members). For this purpose more sophisticated and innovative statistical approaches will be explored. The goal is to provide the best estimate of model skill, especially for the aforementioned variables. The product will be produced in a real-time experimental mode and delivered to HIWPPs data users for evaluation and feedback. The data management will be performed in close collaboration with Real Time IT Operations team. For the product visualization the team will closely work with the Visualization and Extraction via NEIS team.

Outputs & Deliverables

- Development of a statistical technique (e.g. Bayesian averaging) developed into a product running in real-time research mode. This will first be developed with currently available data sets (FIM, GFS and NAVGEM deterministic and ensemble runs with coarser resolution) and then applied to the high-resolution runs.
- The first version of the product running in real-time experimental mode, available to beta testers for evaluation and input.
- A set of refined and additional statistical techniques working with real-time hydrostatic datasets, available for evaluation by interested data users.

Quality Criteria

For the evaluation of the techniques that will be employed in this task, simple ensemble mean of the available ensemble members and the current operational systems will be used as a benchmark. Based on these criteria, the most promising techniques will be considered for the implementation.

Resources

The team will consist of two members. One fulltime employee performing the majority of technical and code development part of the work and a part-time task lead helping coordinate the task work as well as work with other teams:

Human Resources:

- Isidora Jankov - ESRL GSD/CIRA - Task Lead
- CIRES Staff - ESRL GSD/CIRES – Statistical modeling and Data Analysis

Computational Resources:

- Work stations or HPC resources with access to necessary data sources
- Matlab software

Management

The task will be managed by the task lead working closely with the project manager and the laboratory director. The project management process will be as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.5.1 POC, Jankov	3.5 & Project Mgr.	Document
Status Reports	3.5.1 POC, Jankov	3.5 & Project Mgr.	Document, Standardized Status Report Template
Project Advisory	3.5.1 POC, Jankov/	ESRL Lab Director	Meeting

Group	Project Mgr		
Technical Team Meetings	3.5.1 POC, Jankov	Technical Team	Project Management Plan
Sponsor Meetings	ESRL Lab Director, Project Manager, 3.5 Test Mgr. & 3.5.1 POC Jankov	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.5.1 POC, Jankov, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, ESRL Lab Director, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Milestones

Second Quarter of FY14:

- November 2013: Have a full time employee through CIRES on board.
- Sample deterministic (FIM, NAVGEM, and GFS) and ensemble (FIM, GFS) data available to begin post-processing development (March 2014).

Fourth Quarter of FY14:

- A preliminary technique and product determined and tested, and made available through the Test Program for internal testing (August 2014).

First Quarter of FY15:

- Delivery of a real-time product for Visualization, Distribution, and Verification (October 2014).

Second Quarter of FY15:

- A field alignment method, which allows quantification and removal of displacement and amplitude errors, will be evaluated; impact of this method to be determined by Feb 1, 2015.

Fourth Quarter of FY15:

- The most promising methods from all evaluations in FY15 will be implemented into the existing statistical post-processing framework, with the final product available in real-time by Sep 30, 2015

First Quarter of FY16

- Results of collaborations with groups doing ensemble work (such as EMC and Navy) will be evaluated and potential methods for implementation within this framework will be completed by Dec 1, 2015
- A report will be prepared summarizing results through FY15, including investigations of new techniques, the results from those investigations, and software development completed.

Third Quarter of FY16

- Methods to improve precipitation forecasts will be investigated, including methods developed by Tom Hamill on the regional scale for data sample expansion and for downscaling, as part of the Sandy Supplemental Blender project. The feasibility and benefit of applying these methods on a global scale within HIWPP will be evaluated by verifying processed and unprocessed output against observations by May 1, 2015.

Fourth Quarter of FY16

- The most promising methods from all evaluations in FY16 will be implemented into the existing statistical post-processing framework, with the final product available in real-time

Tolerances

Fault	**Tolerance**	**Impact**
A CIRES person on board	February 2014	Starting of the technical work will be delayed
Promising test results	April 2014	Delay of the quasi-operational implementation
Retrospective runs available	August 2014	Delay of the quasi-operational implementation
IT support with real-time runs and quasi-operational implementation	September 2014	Delay of the real-time forecast implementation

Dependencies

- Having the new employee on board not later than February 15, 2014
- Having necessary data sets available (interdependency on GFS, FIM and NAVGEM tasks)

- Have necessary IT support for data transferring and testing of the quasi-operational system in place (interdependency on Real Time IT Operations task)

Risks

- Not having the person employed in time
- Not having the necessary data available in timely manner
- Not being able to get expected improvement by applying various statistical techniques

Scheduling

See above.

Budget

Detailed budgets provided under separate cover.

3.5.2 Visualization & Extraction via NEIS

Task Lead: Jebb Stewart (ESRL/GSD)
Collaborating Groups: ESRL, CIRA, NRL, NCEP

Introduction

Through HIWPP, significant advances in science will be made to improve global prediction systems. Along with improvements to models themselves, advances in visualization and extraction capabilities are necessary to effectively test and evaluate the resulting large volume (i.e. "Big Data") prediction systems. A key part of the evaluation process is the ability to visualize how these experimental models are performing by providing capabilities to integrate other time- and space-matched earth information data in real-time, such as existing global predictions systems and global observations. Through the Test Program Visualization and Extraction task, ESRL will leverage the prototype NOAA Earth Information System (NEIS) and develop an advanced access, visualization and analytics framework using state of the art technology providing on-demand access and integration of experimental global-scale models, and other earth system data. This capability will complement those now present at the operational center (NCEP) by allowing for more extensive testing of new technologies that may be a large departure from the current operational system. It will also allow for more involvement of a diverse community of users in the development, testing and evaluation process, as well as prepare for future systems where data volumes greatly exceed existing bandwidth available to end user systems.

Outputs & Deliverables

September 2014

- An advanced visualization system based on prototype NEIS with the following capabilities:

    - Real-time on-demand access, visualization and integration of time- and space-matched earth system data
    - Basic processing and analytic capability: ensemble means, differencing, probability, etc.
- Data Available through NEIS for at least the last 24 hours:
    - HIWPP Hydrostatic Experimental deterministic global predictions
    - HIWPP Hydrostatic Experimental ensemble global predictions
    - HIWPP Verification Data (3.5.3)
    - Global Operational Models
    - Global Satellite Observations
    - Global Air and Surface Observations
- Bi-Annual Software and Technology Demonstrations
- Development Report (Description of technology, design and related decisions and reasoning)

September 2015

- Improved NEIS Visualization System with the following capabilities:
    - Advanced analytic capabilities allowing generation of new data
    - Improved volumetric data visualization allowing cross section, time-heights, and model-generated soundings
- Bi-Annual Software and Technology Demonstrations
- Development Report (Description of technology, design and related decisions and reasoning)

Quality Criteria

This project will be considered a success if at end of FY 15 the following criteria are met:

- Approved users have real-time access and visualization of experimental deterministic and ensemble prediction data
- Data access methods provide the capability to subset data based on geographic area, temporal range, field, or vertical level
- Users are able to evaluate and test HIWPP experimental global prediction systems through the integration in time and space of the following data:
    - Current Operational global forecast models
    - Global surface observations
    - Global satellite observations
    - Global upper air observations
- Users are able to perform advanced analytic and dynamic processing through the NEIS visualization tool which offers streamlined, intuitive, and extensible user processes

Resources

Human Resources:

- Jebb Stewart - ESRL GSD/CIRA - Task Program Manager and Technical Lead
- CIRA Staff - ESRL GSD/CIRA - Software Engineer

- CIRA Staff - ESRL GSD/CIRA - Software Engineer

Computational Resources:

- Procurement of hardware to support low latency, high throughput virtualization in support of server side visualization software
- Procurement of increased capacity network switch hardware to provide high capacity, low latency throughput to both users and hardware established through the Real-Time IT Operations (3.5.4) Task

Management

The project management team, as outlined in the HIWPP Work Breakdown Structure, is involved in most aspects of the NEIS project management process as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.5.2 POC, Stewart	3.5 & Project Mgr.	Document
Status Reports	3.5.2 POC, Stewart	3.5 & Project Mgr.	Document, Standardized Status Report Template
Project Advisory Group	3.5.2 POC, Stewart/3.5 Test Mgr., Project Mgr	ESRL Lab Director	Meeting
Technical Team Meetings	3.5.2 POC, Stewart	Technical Team	Project Management Plan
Sponsor Meetings	ESRL Lab Director, Project Manager, 3.5 Test Mgr. & 3.5.2 POC Stewart	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.5.2 POC, Stewart, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, ESRL Lab Director, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Project Management Guide

Responsibilities of the Visualization and Extraction task POC/Technical Lead:

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team

- Provide requirements understanding and guidance to the development team
- Identify hardware and software development teams
- Lead software development process: includes team development and resource allocation
- Establish communication plan and schedule with other HIWPP POC's
- Develop tasking, schedule and budget for all aspects of the NEIS development plan in coordination with all GSD Branches involved in development
- Coordinate with other HIWPP project areas to leverage meetings, demonstrations and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting and critical develop monitoring and guidance

Milestones

Second Quarter of FY14:

1. System architecture developed, identifying hardware needed (March 2014)
2. In consultation with EMC, a statement drafted disclaimer") to be applied to HIWPP experimental products (January 2014)
3. Hardware procurement complete (March 2014)

Third Quarter of FY14

4. Initial delivery of prototype NEIS visualization application (April 30, 2014)

Fourth Quarter of FY14:

5. Visualization linked to real-time data (July 31, 2014)

First Quarter of FY15

6. Delivery and demonstration of NEIS client with capability of research grade real-time access and visualization of global model data with integration of time- and space-matched earth information data (October 1, 2014)
7. Integration of verification output into NEIS (December 30, 2014)
8. Development report completed (Description of technology, design and related decisions and reasoning) (October 1, 2014)

Second Quarter of FY15:

9. Initial development of volumetric data visualization and advanced analytic functionality completed and demonstrated. (March 2015)

<u>Fourth Quarter of FY15:</u>

10. Deliver NEIS client with volumetric and advanced analytics visualization capabilities, including advanced verification output (September 2015)
11. Demonstration of Visualization and Extraction software and architecture (September 2015)
12. Final development report completed (Description of technology, design and related decisions and reasoning) (September 2015)

Tolerances

Fault	Tolerance	Impact
Hardware Procurement	March 2013	System Performance: Critical to data storage and retrieval performance.
Real Time IT Operations	July 2014	Real-Time HIWPP data will be unavailable by end of FY14
Verification Data Availability	July 2014	HIWPP Verification data will not be visible in NEIS by end of FY14
Performance requirements met	August 2014	Evaluation and testing process takes longer than expected

Dependencies

The Visualization and Extraction task has identified the following HIWPP task dependencies:

- The success of the Real Time IT Ops task to make HIWPP experimental data
- The Test Program depends upon the success of this project to make data available to a community of users for evaluation and testing
- The success of this task depends upon the Hydrostatic Global Models and Non-Hydrostatic Models tasks to generate experimental models available for evaluation and the Verification task to make verification data available

The following additional dependencies outside HIWPP have been identified:

- This task depends on the procurement of hardware in reasonable time necessary to meet high throughput and capacity demands

Risks

The Visualization and Extraction task has identified the following risks:

Hardware Risks
- Procurement process could take longer than expected and hardware is not in place by March 2014
- Procurement costs could be higher than expected

Tasks Risks
- Real-Time IT Operations Task (3.5.4) is unable to provide data within expected time
- Verification Task (3.5.3) is unable to provide data within expected time
- Hydrostatic Modeling tasks are unable to produce global experimental prediction data

Development Risks
- Unforeseen challenges with encoding strategies for data dissemination
- System delivered does not meet the expectations of the target users in terms of functionality and usability
- Data volume exceeds initial estimates
- Unexpected increase in both frequency and size of user base.
- Resources run out before task is completed

Scheduling
Based on the Visualization and Extraction Milestones, here is the scheduling:
- Milestone 3 requires milestone 1 to be complete
- Milestone 4 requires both milestone 3 to be complete
- Milestone 6 requires milestones 4 and 5 to be complete
- Milestone 9 requires milestone 6 to be complete
- 10 and 11 require milestone 9 to be complete

Budget
Detailed budgets provided under separate cover.

3.5.3 Verification Methods

Task Lead: Bonny Strong (ESRL/GSD)
Collaborating Groups: ESRL, NRL, NCEP, CIRA, CIRES

Introduction
Through HIWPP, significant scientific advances will be made to improve global prediction systems. In order to evaluate that progress and inform decisions regarding the best paths to pursue, a consistent verification procedure (same measures, software, and truth data sets) must be applied to all forecast experiments. This consistency of certification is essential for project success and this verification task will be responsible for construction of the verification system and application of it to the experiment forecasts. The verification performed under this task will

constitute the official HIWPP verification. This consistency and uniformity is important for the credibility of the verification results.

Considerable verification expertise exists within ESRL and EMC and an efficient, flexible, and accessible verification system will be built from existing verification modules. Many of the needed pieces for this system are already in place among the member groups, and the goal of this task is not to build a new system from scratch but rather to: 1) leverage the existing pieces to quickly put in place a suitable base-line system, 2) as resources allow, add additional verification components to arrive at a consolidated system that will serve the HIWPP effort and subsequent modeling efforts and 3) apply the verification system to HIWPP experiment forecasts. An important outcome of this work will be the blending of current verification capabilities among member groups into a unified system that incorporates the best components from the existing systems. The unified system will serve as a framework, in which newer capabilities, including enhanced ensemble verification scores, multi-parameter scorecard measures, and increased emphasis on sensible weather verification can be added. The variables to be included in the scorecard will include upper-air and surface and precipitation verification. The upper-air verification will include grid and observation-point verification. Some measures will focus on verification of high impact weather, such as precipitation, surface winds, and hurricane tracks near the United States.

A key attribute for the verification system is a statistical score database and interactive web interface that will facilitate rapid, user selectable stratification options for the skill score data based on a variety of different parameters (time-series, lead-time, spatial region, scale, skill measure, threshold, valid time of day, selectable models, differences, etc.). The HIWPP system must handle a variety of different models (non-hydrostatic and hydrostatic, real-time and retrospective) and verification fields (surface and upper-air observations, precipitation, radar and satellite data, and model analyses). Finally, the short-term requirement for the baseline system is dictated by the need to rapidly move forward on the hydrostatic evaluation portion of HIWPP.

Outputs & Deliverables

- A unified HIWPP verification framework based on the existing EMC (VSDB) system for verification of initial hydrostatic deterministic model retrospective and real-time runs, plus selected ensembles produced as part of HIWPP, with an initial set of baseline metrics defined and results archived.
- A definition of a common set of metrics, standards, and format for an advanced HIWPP verification system, prepared in coordination with project participants.
- A mid-range verification system based on a MySQL database with an interface to the baseline system components.

- An advanced HIWPP verification system with possible enhancements for ensemble verification, multi-parameter scorecard verification, and enhanced sensible weather verification.
- Verification runs of HIWPP real-time and retrospective experiments.
- A unified verification report.

Quality Criteria

This project task will be considered a success if at end of FY 15 the following criteria are met:

- A unified, verification system that meets the HIWPP needs has been assembled from existing components.
- Some enhancements for ensemble verification, multi-parameter scorecards, and expanded sensible weather verification have been added to the verification system.
- HIWPP participants are obtaining crucial verification information to inform decision-making concerning model development and evaluation.
- Users are able to perform advanced interactive customized evaluation of model performance through a wide range of individual and composite metrics and user defined verification attributes.

Resources

Human Resources:

- Steve Weygandt – ESRL GSD - Task Lead for GSD (0.05 FTE)
- NCEP EMC – Task lead for EMC (0.05 FTE)
- CIRES Staff – ESRL GSD/CIRA – Meteorologist (0.5 FTE)
- EMC Staff – NCEP EMC – Meteorologist (0.5 FTE)

Computational Resources:

- Use of existing hardware resources (ZEUS and other NOAA computers)

Management

The project management team as outlined in the HIWPP Work Breakdown Structure is involved in most aspects of the NEIS project management process as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.5.3 POC, Strong	3.5 & Project Mgr.	Document
Status Reports	3.5.3 POC, Strong	3.5 & Project Mgr.	Document, Status Report Template
Project Advisory Group	3.5.3 POC, Strong/ 3.5 Test Mgr., Project Mgr	ESRL Lab Director	Meeting

Technical Team Meetings	3.5.3 POC, Strong	Technical Team	Project Management Plan
Sponsor Meetings	ESRL Lab Director, Project Manager, 3.5 Test Mgr. & 3.5.3 POC Strong	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target Presentations	3.5.3 POC, Weygandt, 3.5 Test Mgr., Project Mgr.	Project Advisory Group, ESRL Lab Director, Users, NOAA/OAR HIWPP Management	Presentation and Discussion

Project Management Guide
Responsibilities of the Verification Methods task POC/Technical Lead:

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team
- Provide requirements understanding and guidance to the development team
- Coordinate initial implementation of existing verification software and planning for unification of software and addition of new capabilities
- Establish communication plan and schedule with other HIWPP POC's
- Develop tasking, schedule and budget for all aspects of the verification system development plan in coordination with all groups involved in development
- Coordinate with other HIWPP project areas to leverage meetings, demonstrations and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting and critical develop monitoring and guidance

Milestones

Second Quarter of FY14:

1. Preliminary testing of new virtual machine for database (March 2014)
2. Test runs of EMC deterministic verification system (March 2014)

Third Quarter of FY14:

3. Human resources in place for code development and management (June 2014)

Fourth Quarter of FY14:

4. Delivery of prototype system based on EMC (VSDB) for initial verification capabilities for hydrostatic model runs (August 2014)
5. Metrics, standards, and formats for advanced verification system completed with participation of project members (August 2014)
6. Verification metrics produced and archived for hydrostatic retrospective model runs and selected ensemble products (September 2014)

First Quarter of FY15:

7. Verification metrics produced and archived for hydrostatic real-time model runs and selected ensemble products (December 2014)
8. Mid-range verification completed and available to project members (December 2014)

Second Quarter of FY15:

9. Ongoing verification of retrospective and real-time experiments with mid-range verification system (March 2015)

First Quarter of FY16:

10. Advanced verification system completed (November 2015)
11. Advanced verification package being used for all HIWPP verification (December 2015)

Second Quarter of FY16

12. Complete and deliver final Verification Task report (Description of technology, design, discussion of results and decisions made based on verification tools) (June 2016)

Tolerances

Fault	Tolerance	Impact
Initial verification capability	No more than 1 month after scheduled date of Mar 2014	Initial capability critical for evaluation of early hydrostatic expt. runs
Mid-range verification capability	No more than 2 months after scheduled date of Dec. 2014	Mid-range capability critical for evaluation and decision-making on non-hydrostatic expt. runs
Mature verification capability	Unable to complete in timely manner	Detailed evaluation and testing process for non-hydrostatic models takes longer than expected

Dependencies

The Verification Methods task has identified the following HIWPP task dependencies:

- The success of the Real Time IT Ops task to make HIWPP experimental data available to this task.
- The success of this task depends upon the Hydrostatic Global Models task to generate experimental models available for evaluation.

Risks

The Verification Methods task has identified the following risks:

Management Risks

- Resources are insufficient to complete all the tasks required for assembling the verification sys and completing all the verification work.

Development Risks

- Unforeseen technical challenges with merging the existing capabilities
- System delivered does not meet the needs of the target users in terms of functionality and usability.

Scheduling

Based on the Verification Methods Milestones, here is the scheduling.

Milestone 4 requires milestone 1 to be complete.
Milestones 5 and 7 require milestone 4 to be complete.
Milestone 8 requires milestones 2 and 3 to be complete.
Milestone 9 requires 8 to be complete
Milestone 10 requires 5 to be complete
Milestone 11 requires 10 to be complete

Budget

Detailed budgets provided under separate cover. See also Section 4.0.

3.5.4 Real Time IT Operations

Task Lead: Bonny Strong (ESRL/GSD & CIRA)
Collaborating Groups: ESRL, CIRA, NRL, NCEP

Introduction

Real-Time IT Operation task is the foundation of the Test Program and facilitates the testing and evaluation of experimental global numerical weather prediction systems. A significant portion of this task is the overall management of the Test Program to ensure each subtask is meeting its milestones and deliverables towards the overall success of HIWPP, and to provide coordination between the Test Program and other sub-projects within HIWPP.

The other significant portion of this task is to provide, monitor, and support an IT infrastructure for the distribution, testing and evaluation of data related to the HIWPP program. This task will leverage the existing IT infrastructure and personnel available at ESRL/GSD. The ESRL/GSD Central Facility infrastructure includes high bandwidth networking, enterprise storage systems and Virtual Machine (VM) resources that support GSD model development and evaluation activities. Further, software services have been developed to provide data acquisition, processing and monitoring of numerous needed data sets, presently comprising over 600 data types and more than one terabyte per day. These systems provide resources that serve the needs of both internal users and external collaborators, who obtain data sets via distribution methods provided by secure DMZ services. To ensure that these systems and services run reliably, GSD's Systems Support Group provides 24x7 monitoring and troubleshooting coverage; this team is available via email and phone contact for both internal users and external collaborators.

While this infrastructure supports the existing data needs, research and development are required to improve and enhance these capabilities to support the next generation large volume global prediction systems data needed by other Test Program tasks (3.5.1, 3.5.2, and 3.5.3). This task will continue ESRL research into novel file, storage, and processing systems to meet the project’s storage, throughput, and latency requirements while maintaining the best possible cost point.

Outputs & Deliverables

- Enhanced IT infrastructure to support distribution and evaluation of HIWPP data, including new hardware and software components.
- Real-time distribution of HIWPP model data to project team members and external data users.
- Services enabling the ability to ex tract full and subset (regional, level, field) data, delivered to a diverse community of users.
- Acquisition of non-model data needed for visualization or verification, including observant ions, satellite images, or other data as agreed by project members, and distribution of these data to project team members.
- Planning, monitoring, and support to ensure high availability of critical data with 24/7/365 coverage. Support available by phone or email to HIWPP and community members.
- Documentation to provide monitoring and troubleshooting guidance to Systems Support Group, and training to the group on how to respond to data issues.
- Provision of a community portal to facilitate project collaboration and provide publicly available information about the project.

Quality Criteria

This project will be considered a success if at the end of FY 15 the following criteria are met:

- A community portal is available allowing information exchange between HIWPP partners and the community of users
- An Enhanced IT infrastructure is developed and in place to support the next generation of high resolution global forecast systems and allows the completion of other Test Program subtasks (3.5.1, 3.5.2, and 3.5.3.)
- Support is available to answer questions regarding HIWPP data or services
- Monitoring is in place ensuring best uptime available for data and services

Resources

Bonny Strong CIRA - ESRL GSD/CIRA - Test Program Project Manager
ESRL GSD - System Support Group (SSG), Data Services Group (DSG), System Administration Staff, and Networking Team

Computational Resources:

- Procurement of storage and processing hardware to support testing and evaluation of HIWPP data.
- Procurement of high-capacity network switch hardware to provide high-capacity low-latency throughput to both data providers and hardware procured through the Visualization and Extraction (3.5.2) Task.

Management

The project management team as outlined in the HIWPP Work Breakdown Structure is involved in most aspects of the project management process as follows:

What	Who's Responsible	Target Audience	Method
Project Plan	3.5.4 POC, Strong	Project Mgr.	Document
Status Reports	3.5.4 POC, Strong	Project Mgr.	Document, Standardized Status Report Template
Project Advisory Group	3.5.4 POC, Strong, Project Mgr	ESRL Lab Director	Meeting
Technical Team Meetings	3.5.4 POC, Strong	Technical Team	Project Management Plan
Sponsor Meetings	ESRL Lab Director, Project Manager & 3.5.4 POC Strong	NOAA/OAR HIWPP Management	Meeting and/or Presentation
Periodic Demos and Target	3.5.4 POC, Strong, Project Mgr.	Project Advisory Group, ESRL Lab	Presentation and Discussion

Presentations		Director, Users, NOAA/OAR HIWPP Management	

Project Management Guide

Responsibilities of the Real Time IT Operations task POC/Technical Lead:

- Create the task development plan in coordination with the development team and the ESRL HIWPP management team
- Provide requirements, understanding, and guidance to the development team
- Establish hardware and software development teams
- Lead software development process: includes team development and resource allocation
- Establish communication plan and schedule with other HIWPP POC's
- Develop tasking, schedule and budget for all aspects of the plan in coordination with all GSD Branches involved in development
- Coordinate with other HIWPP project areas to leverage meetings, demonstrations, and project activities to achieve project management efficiencies
- Responsible for milestone management, status reporting, and critical develop monitoring and guidance

Milestones

Second Quarter of FY14:

1. Community portal set up and available to project members (February 2014)
2. Data requirements and data flow for first year of project defined and documented (March 2014)
3. Storage hardware procurement initiated (March 2014)
4. POC's between HIWPP initial data partners established (March 2014)

Third Quarter of FY14:

5. Plan in place to acquire all HIWPP required data in GSD's Central Facility (April 2014)
6. Storage hardware procured and ready to install (May 1, 2014)
7. Software components for data distribution completed (June 15, 2014)
8. Installation and testing of enhanced IT infrastructure completed (June 15, 2014)

9. Initial data from HIWPP members are flowing and available on Real-Time IT Operations infrastructure in GSD's Central Facility ready for internal testing (June 2014)

<u>Fourth Quarter of FY14:</u>

10. Real-Time monitoring in place ensuring data and services are available as expected (September 2014)
11. Support procedures in place and communicated to project members and external data users (September 2014)
12. Task report completed (September 2014)

<u>First Quarter of FY15:</u>

13. Real-time distribution of HIWPP hydrostatic deterministic and Statistical Post-Processing global model data are reliably available to initial external data users (December 31, 2014)

<u>Second Quarter of FY15:</u>

14. Any necessary changes to the community portal, real time monitoring, or IT infrastructure have been completed (December 2014)

<u>Third Quarter of FY15:</u>

15. Feedback from external data users has been collected and made available to project members (April 2015)

<u>Fourth Quarter of FY15:</u>

16. Final task report completed (September 2015)

Tolerances

Fault	Tolerance	Impact
Hardware Procurement Initiated	March 2014	Other tasks dependent on this one may require additional time
HIWPP Target Data Availability	July 2014	Other tasks dependent on this one may require additional time
Performance	August 2014	Evaluation and testing process takes longer than expected

Dependencies

The Real-Time IT Operations task has identified the following HIWPP task dependencies:

- The Visualization and Extraction task depends upon the success of this task to make data available to a community of users for evaluation and testing.

- The Test Program depends upon the success of this task.
- The success of these tasks depends on availability of target experimental global prediction data from the Hydrostatic Modeling tasks. HIWPP experimental data needs to be produced and transferred to ESRL in timely manner to allow other tasks of the Test Program to succeed.

The following additional dependencies outside HIWPP have been identified:
This task depends on the procurement of storage, compute, and networking hardware for staging model results for the community for subsequent analysis and verification

Risks

- Inability to size the data distribution systems for required volume and throughput
- Procurement timeline slips
- Unable to acquire “off-site” HIWPP data in timely manner
- Hardware installation and setup issues
- Storage and compute system performance not meeting expectations
- Support requests exceed staff resources available to handle them
- Unable to achieve expected results because of resource shortfall

Scheduling

Based on the Real Time IT Operations, here is the scheduling:
Milestone 3 depends on 2 being complete.
Milestone 6 depends on 3 being complete.
Milestone 7 depends on 2 being complete.
Milestone 8 depends on 6 being complete.
Milestone 9 depends on milestones 5, 7, and 8.
Milestone 13 depends on milestones 9, 10, and 11.

Budget

Detailed budgets provided under separate cover.

Appendix A: Collected Milestones & Deliverables

HIWPP Milestones From Project Plan August 2015 (Ver 3.1)					
Task num	**Task name**	**Date Due**	**Description**	**Due - Qtr**	**Due - Fiscal Year**
3.0	Proj Mgmt	10/31/13	Complete detailed project plan	Q1	2014
3.0	Proj Mgmt	06/30/14	Establish project web page	Q3	2014
3.0	Proj Mgmt	09/30/16	Project Completion	Q4	2016
3.0	Proj Mgmt	09/30/16	Final project report completed and submitted to EOB	Q4	2016
3.1	Hydrostatic Models	03/31/14	Identify participants, computer resources, and determine model configurations for hydrostatic tests	Q2	2014
3.1	Hydrostatic Models	06/30/14	Begin retro testing and tuning of 4D-En-Var with high-res GFS	Q3	2014
3.1	Hydrostatic Models	06/30/14	Begin retro runs of all hydrostatic models	Q3	2014
3.1	Hydrostatic Models	09/30/14	Implementation of improved higher res GFS	Q4	2014
3.1	Hydrostatic Models	09/30/14	Config of 4D-En-Var finalized and begin cycling forecasts	Q4	2014
3.1	Hydrostatic Models	08/31/14	Prelim retro runs may be available	Q4	2014
3.1	Hydrostatic Models	09/30/14	Retro deterministic runs complete for FIM, NAVGEM. Complemented by GFS real-time parallel tests and retro GFS runs at ESRL.	Q4	2014
3.1	Hydrostatic Models	12/30/14	Implementation of higher res GEFS, GSI	Q1	2015
3.1	Hydrostatic Models	10/31/14	Decision made on quasi-real-time ensembles. Quasi-real-time deterministic and ensemble forecasts available. Decision on mini ensemble of high-res models made.	Q1	2015
3.1	Hydrostatic Models	12/30/14	Configuration finalized for quasi-real-time high-res runs	Q1	2015

3.1	Hydrostatic Models	12/31/14	Begin quasi-real-time, high resolution runs of deterministic and ensemble hydrostatic forecasts	Q1	2015
3.1	Hydrostatic Models	03/31/15	Feedback from beta testers collected and synthesized.	Q2	2015
3.1	Hydrostatic Models	06/30/15	Draft report for submission to peer-reviewed journal.	Q4	2015
3.1	Hydrostatic Models	09/30/15	Final report submitted to peer-reviewed journal.	Q2	2016
3.1.1	DA/Ens /Physics	03/31/14	Parameters for stochastic physics tuned for DA and medium-range EPS using T574L64 semi-Lagrangian GFS ensemble.	Q2	2014
3.1.1	DA/Ens /Physics	03/31/14	Testing of EnKL TC relocation scheme finished	Q2	2014
3.1.1	DA/Ens /Physics	06/30/14	Incremental analysis update (IAU) implemented and tested within 4D-En-Var using GFS model	Q3	2014
3.1.1	DA/Ens /Physics	06/30/14	Balance constraint for EnKL analysis implemented and tested using GFS model	Q3	2014
3.1.1	DA/Ens /Physics	09/30/14	Initial configuration of quasi-real-time 4D-EnVar analysis system complete	Q4	2014
3.1.1	DA/Ens /Physics	03/31/15	Results of 4D-EnVar testing used to recommend a preliminary test package to NCEP/EMC as a candidate for operational implementation	Q2	2015
3.1.1	DA/Ens /Physics	12/30/15	Interface to 4D-En-Var GSI system completed for selected non-hydrostatic core	Q1	2016
3.1.1	DA/Ens /Physics	12/30/15	Stochastic microphysics scheme ported to selected dycores	Q1	2016
3.1.1	DA/Ens /Physics	09/30/16	Evaluation complete for impact of stochastic microphysics scheme in cycled non-hydro DA and forecast system	Q4	2016
3.1.1	DA/Ens /Physics	09/30/16	Evaluation complete of selected non-hydro model within cycled 4D-En-Var system	Q4	2016
3.1.2	Parameterizations (1)	12/31/13	Hire postdoc at NCEP	Q1	2014

3.1.2	Parameterizations (1)	12/31/13	Begin including new physics modules in based on GFS	Q1	2014
3.1.2	Parameterizations (1)	09/30/15	Test and evaluate NCEP global model interacting with new physics modules at low resolution	Q4	2015
3.1.2	Parameterizations (1)	09/30/15	Tune physics as necessary	Q4	2015
3.1.2	Parameterizations (1)	12/31/15	Test and evaluation NCEP global model interacting with new physics modules at medium ("climate") resolution	Q1	2016
3.1.2	Parameterizations (1)	12/31/15	Physics tuned if necessary	Q1	2016
3.1.2	Parameterizations (1)	06/30/16	Test and evaluate NCEP global model interacting with new physics modules at full resolution.	Q3	2016
3.1.2	Parameterizations (1)	06/30/15	Test in forecast-assimilation cycles.	Q3	2016
3.1.2	Parameterizations (1)		Testing begun to perform medium-range NWP forecasts with prescribed initial conditions from operational Global Data Assimilation System (GDAS) [Milestone removed, 8/5/15 due to late project start and hiring]		
3.1.2	Parameterizations (2)	07/01/14	CIRES scientist hired	Q2	2014
3.1.2	Parameterizations (2)	09/30/14	Tuning of stochastic convective parameterization using EMC evaluation metrics finished	Q4	2014
3.1.2	Parameterizations (2)	09/30/15	Implementation and evaluation of aerosol awareness using observed and simulated AOD completed	Q2	2015
3.1.2	Parameterizations (2)	09/30/15	Evaluation of scale awareness for case studies and shorter periods in non-hydrostatic modeling system finished	Q4	2015
3.1.2	Parameterizations (2)	09/30/15	Peer reviewed publication submitted	Q4	2015

3.1.3	GFS	03/31/14	Support scientists hired and trained; starting to collect GEFS initial conditions including initial perturbations	Q2	2014
3.1.3	GFS	06/30/14	Started retrospective forecasts	Q3	2014
3.1.3	GFS	09/30/14	Forecast data exchanged with partners; statistical post-processing begun.	Q4	2014
3.1.3	GFS	12/30/14	Retrospective runs complete, multi-model evaluation and verification begun.	Q1	2015
3.1.3	GFS	03/31/15	Statistical post-processing complete; exchange of data complete.	Q2	2015
3.1.3	GFS	06/30/15	Evaluation and verification complete. Comparison of experimental NAEFS including the FIM ensemble with operational NAEFS begun.	Q3	2015
3.1.3	GFS	09/30/15	Comparison complete of experimental NAEFS including FIM ensembles with operational NAEFS. Summary report and/or scientific manuscript written.	Q4	2015
3.1.4	FIM	03/31/14	Identify participants, computer resources, and determine model configurations for hydrostatic tests	Q2	2014
3.1.4	FIM	04/01/14	Begin retrospective runs of FIM hydrostatic model for deterministic and ensemble forecasts	Q3	2014
3.1.4	FIM	06/30/14	Initial FIM verification results produced for retro runs	Q3	2014
3.1.4	FIM	11/15/14	Retro runs for 1-yr period for deterministic forecasts complete	Q1	2015
3.1.4	FIM	12/30/14	Configuration finalized for quasi-real-time high-res runs	Q1	2015
3.1.4	FIM	10/31/14	Decision made on quasi-real-time ensembles. Quasi-real-time deterministic and ensemble forecasts available. Decision on mini ensemble of high-res models made.	Q1	2015
3.1.4	FIM	01/01/15	Begin quasi-real-time, high resolution runs of deterministic and ensemble hydrostatic forecasts	Q2	2015
3.1.4	FIM	03/31/15	Feedback from beta testers collected and synthesized.	Q2	2015

3.1.4	FIM	09/30/15	Draft report for submission to peer-reviewed journal.	Q4	2015
3.1.4	FIM	03/31/16	Final report submitted to peer-reviewed journal.	Q2	2016
3.1.5	NAVGEM	12/30/13	NAVGEM software for high-resolution ported	Q1	2014
3.1.5	NAVGEM	06/30/14	NAVGEM dynamic core and model physics improved toward the targeted resolutions	Q3	2014
3.1.5	NAVGEM	03/30/14	Software adapted and tested to produce forecast model output in appropriate format	Q1	2015
3.1.5	NAVGEM	06/30/14	Limited retro runs examined for quality control and output format	Q1	2015
3.1.5	NAVGEM	09/30/14	High-res and ensemble NAVGEM run for year-long retrospective time period.	Q1	2015
3.1.5	NAVGEM	01/01/15	Begin quasi-real-time ensemble and high-res forecasts	Q2	2015
3.1.5	NAVGEM	03/31/16	Participated in evaluation of multi-model ensemble forecasts	Q2	2016
3.2	Non-Hydrostatic Models	06/01/14	Baroclinic wave DCMIP test cast 4.1.0 delivered to Task Lead	Q3	2014
3.2	Non-Hydrostatic Models	07/01/14	Orographic gravity wave test case on a scaled small planet delivered to Task Lead.	Q4	2014
3.2	Non-Hydrostatic Models	08/01/14	Idealized supercell test case on a scaled small planet delivered to Task Lead	Q4	2014
3.2	Non-Hydrostatic Models	09/01/14	Optional tropical cyclone test case (DCMIP 5.1) delivered to Task Lead	Q4	2014
3.2	Non-Hydrostatic Models	10/01/14	Report synthesizing the results of submitted tests completed	Q4	2014
3.2	Non-Hydrostatic Models	11/30/14	Modeling groups deliver preliminary benchmark packages	Q1	2015
3.2	Non-Hydrostatic Models	02/15/15	Final benchmark codes ready	Q2	2015

3.2	Non-Hydrostatic Models	03/01/15	2-3 day global forecasts run by all models at 3 km, initialized from NCEP GDAS analysis	Q2	2015
3.2	Non-Hydrostatic Models	06/01/15	Report on all idealized, 3-km real-data tests, and benchmark results completed	Q3	2015
3.2	Non-Hydrostatic Models	10/01/15	Level-2 testing of selected dycores completed in conjunction with NGGPS	Q4	2015
3.2.3	MPFG/ GPU Optimizations	03/30/14	NIM benchmark code ready for MPFG procurement	Q2	2014
3.2.3	MPFG/ GPU Optimizations	12/31/14	NIM dynamics optimized for MPFG on TACC	Q1	2015
3.2.3	MPFG/ GPU Optimizations	03/30/15	MPFG parallelization of GFS physics to FIM and NIM completed, integrated with dynamics, tested on TACC, ORNL	Q2	2015
3.2.3	MPFG/ GPU Optimizations	04/01/15	Computational benchmark tests prepared and run jointly with NGGPS for all non-hydro dycores	Q3	2015
3.2.3	MPFG/ GPU Optimizations	09/30/15	Updated MPFG parallelization for FIM,NIM completed	Q4	2015
3.2.3	MPFG/ GPU Optimizations	12/30/15	Performance optimized for NIM and beginning to run on MPFG system	Q1	2016
3.2.3	MPFG/ GPU Optimizations	12/30/15	Parallelization of selected non-hydrostatic model in progress on new MPFG system	Q1	2016

3.3	Moving Hurricane Nests	02/28/14	Initial training on NMMB/NEMS completed; HPC resources procured; development branchin within EMC subversion set up; HWRF components for transition to NMMB/NEMS identified/prioritized	Q2	2014
3.3	Moving Hurricane Nests	06/30/14	NMMB configured as research model for hurricanes; implementation of HWRF vortex initialization scheme in NMMB begun; implementation of HWRF nest motion algorithm in NMMB begun; transition to jet continuing.	Q3	2014
3.3	Moving Hurricane Nests	09/30/14	NMMB for hurricane forecasts mimics operational HWRF configuration; idealized capability for simulations developed; HWRF physics schemes and vortex initialization implemented	Q4	2014
3.3	Moving Hurricane Nests	12/30/14	Implementation of appropriate physics suite from HWRF completed; HWRF nest upgrades transitioned to NMMB; physics and dynamics tuned	Q1	2015
3.3	Moving Hurricane Nests	12/30/14	Vortex initialization completed; effectiveness of 2-way nesting, physics and vortex initialization for NMMB confirmed in case studies.	Q2	2015
3.3	Moving Hurricane Nests	03/31/15	Preliminary tests completed on NMMB nest testing with HWRF physics and vortex initialization for tropical cyclone case studies	Q2	2015
3.3	Moving Hurricane Nests	06/30/15	Multiple telescopic 2-way nesting in multi-scale NMMB/NEMS completed and tested.	Q3	2015
3.3	Moving Hurricane Nests	06/30/15	Report completed on NMMB nest testing with HWRF physics and vortex initialization for tropical cyclone case studies	Q3	2015
3.3	Moving Hurricane Nests	06/30/15	Physics and vortex initialization fine tuned for hurricane applications	Q3	2015
3.3	Moving Hurricane Nests	09/30/15	Large scale retro tests performed; retuning completed if needed; effectiveness of nest motion algorithm in NMMB framework confirmed.	Q4	2015

3.3	Moving Hurricane Nests	12/30/15	Evaluation of storm structure and rainfall forecasts for land-falling storms complete	Q1	2016
3.3	Moving Hurricane Nests	12/30/15	Report completed based on retro runs	Q2	2016
3.4	NMME	07/31/14	Archive of enhanced NMME data for public access completed	Q4	2014
3.4	NMME	01/31/15	Evaluations of NMME-based hurricane seasonal outlook completed	Q2	2015
3.4	NMME	03/31/15	NMME-based hurricane seasonal outlook procedure completed	Q2	2015
3.4	NMME	04/30/15	Real-time test of NMME-based hurricane seasonal outlook completed	Q3	2015
3.4	NMME	04/30/15	Final completion of archive of enhanced NMME data for public access	Q3	2015
3.4	NMME	09/30/15	Evaluation of NMME-based severe weather environmental factors completed	Q4	2015
3.5.1	Statistical Post Processing	03/31/14	Sample deterministic and ensemble data collected	Q2	2014
3.5.1	Statistical Post Processing	08/01/14	Preliminary technique and product available to Test Program for testing	Q4	2014
3.5.1	Statistical Post Processing	09/30/14	Real-time Statistical Post Processing product available	Q4	2014
3.5.1	Statistical Post Processing	02/01/15	Field alignment method evaluated	Q2	2015
3.5.1	Statistical Post Processing	06/30/16	Methods to improve precip forecasts from Blender project evaluated	Q3	2016
3.5.1	Statistical Post Processing	09/30/15	Most promising methods from FY15 evaluations implemented and integrated into existing framework	Q4	2015
3.5.1	Statistical Post Processing	12/01/15	Report prepared summarizing results through FY15 including investigations of new techniques and software developed.	Q1	2016

3.5.1	Statistical Post Processing	12/01/15	Results of collaboration with groups doing ensemble work evaluated	Q1	2016
3.5.1	Statistical Post Processing	09/30/16	Most promising methods from FY16 evaluations implemented and integrated into existing framework	Q1 Q4	2016
3.5.2	NEIS	03/31/14	System architecture developed and hardware requirements identified	Q2	2014
3.5.2	NEIS	03/31/14	Disclaimer drafted for HIWPP experimental products, with EMC	Q2	2014
3.5.2	NEIS	03/31/14	Hardware procurement requisition complete	Q2	2014
3.5.2	NEIS	04/30/14	Beta NEIS version 1 system complete	Q3	2014
3.5.2	NEIS	07/31/14	Visualization linked to real-time data	Q4	2014
3.5.2	NEIS	10/01/14	Delivery and demo of NEIS version 1 system and development report completed	Q1	2015
3.5.2	NEIS	12/30/14	Integration of verification output into NEIS completed	Q1	2015
3.5.2	NEIS	03/30/15	Beta NEIS version 2 system complete, with volumetric and advanced analytics capabilities	Q2	2015
3.5.2	NEIS	09/30/15	Delivery and demo of NEIS version 2 system and final development report completed	Q4	2015
3.5.3	Verification	03/31/14	Preliminary testing of new VM for DB completed	Q2	2014
3.5.3	Verification	03/31/14	Test runs of EMC deterministic verification for HIWPP completed	Q2	2014
3.5.3	Verification	06/30/14	Human resources in place for code development	Q3	2014
3.5.3	Verification	08/01/14	Prototype system based on EMC (VSDB) system available for verification of hydrostatic model runs	Q4	2014
3.5.3	Verification	08/01/14	Metrics, standards, and formats for advanced verification system completed with participation of project members	Q4	2014
3.5.3	Verification	09/30/14	Verification metrics for hydrostatic retro model runs and selected ensemble products produced and archived	Q4	2014

3.5.3	Verification	12/30/14	Verification metrics for hydrostatic real-time model runs and selected ensemble products produced and archived	Q1	2015
3.5.3	Verification	12/30/14	Mid-range verification system based with MySQL database completed and available to project members	Q1	2015
3.5.3	Verification	12/30/15	Advanced verification system with new capabilities completed	Q1	2016
3.5.3	Verification	12/30/15	Advance verification system used for for HIWPP verification	Q1	2016
3.5.3	Verification	03/30/16	Final report completed	Q2	2016
3.5.4	Real-time IT Ops	03/31/14	Community portal available for project	Q2	2014
3.5.4	Real-time IT Ops	03/31/14	Storage purchase requisition completed	Q2	2014
3.5.4	Real-time IT Ops	03/31/14	Data requirements for project year 1 defined and documented	Q2	2014
3.5.4	Real-time IT Ops	04/30/14	Plan in place to acquire all HIWPP required data in GSD's Central Facility	Q3	2014
3.5.4	Real-time IT Ops	05/31/14	Storage hardware procured and ready to install	Q3	2014
3.5.4	Real-time IT Ops	06/15/14	Software components for data distribution completed	Q3	2014
3.5.4	Real-time IT Ops	06/15/14	Enhanced IT infrastructure in place and tested, including hardware and software components	Q3	2014
3.5.4	Real-time IT Ops	06/30/14	Initial data from HIWPP members are flowing and available on Real-Time IT Ops infrastructure for internal testing	Q3	2014
3.5.4	Real-time IT Ops	09/30/14	Real-time monitoring and support in place. Task report completed.	Q4	2014
3.5.4	Real-time IT Ops	12/31/14	Real-time distribution of hydrostatic model data reliably available through Open Data Initiative	Q1	2015
3.5.4	Real-time IT Ops	12/31/14	Any necessary changes to community portal, real time monitoring, or IT infrastructure completed	Q1	2015
3.5.4	Real-time IT Ops	04/30/15	Feedback from Open Data Initiative collected and made available to project members	Q3	2015

3.5.4	Real-time IT Ops	06/30/16	Final report completed	Q2	2016

Appendix B: Acronyms & Abbreviations

3DVAR: 3-Dimensional Variational data assimilation system
4D-En-Var: 4-Dimensional Ensemble Variational data assimilation system
4DVAR: 4-Dimensional Variational data assimilation system
AOML: Atlantic Oceanographic and Meteorological Laboratory
AWC: Aviation Weather Center
CCPA: Climatology-Calibrated Precipitation Analysis
CICS-P: Cooperative Institute for Climate Science – Princeton University
CIMAS: Cooperative Institute for Marine and Atmospheric Studies
CIRA: Cooperative Institute for Research in the Atmosphere
CIRES: Cooperative Institute for Research in Environmental Sciences
CoG: Commodity Governance
CPC: Climate Prediction Center
CPT: Climate Process Team
CPU: Central Processing Unit
CSM: Climate System Model
DA: Data assimilation
DCMIP: Dynamical Core Model Intercomparison Project
Dycore: Dynamical core
ECMWF: European Centre for Medium-Range Weather Forecasts
EMC: Environmental Modeling Center
EnKF: Ensemble Kalman-Filter data assimilation system
EOB: Executive Oversight Board
ESMF: Earth System Modeling Framework
ESRL: Earth System Research Laboratory
FIM: Flow-following finite volume Icosahedral Model
FMS: Financial Management Center
FTE: Full-Time Employee
GDAS: Global Data Assimilation System
GEFS: Global Ensemble Forecast System
GFDL: Geophysical Fluid Dynamics Laboratory
GF: Grell-Freitas parameterization scheme
GFS: Global Forecast System
GIS: Geographic Information System
GOCART: Goddard Chemistry Aerosol Radiation and Transport Model
GPU: Graphics Processing Unit
GRIB: GRIdded Binary
GSD: Global Systems Division
GSI: Gridpoint Statistical Interpolation

GSM: Global Spectral Model
GUI: Graphical User Interface
HiRAM: High Resolution Atmospheric Model
HIWPP: High-Impact Weather Prediction Project
HFIP: Hurricane Forecast Improvement Project
HPC: High-Performance Computing
HWRF: Hurricane Weather Research and Forecasting
IAU: Incremental Analysis Update
MIC: Many Integrated Core
MME: Multi-model ensemble
MPAS: Model for Prediction Across Scales
MPFG: Massively Parallel Fine Grain
MSC: Meteorological Service of Canada
NAEFS: North American Ensemble Forecast System
NASA: National Aeronautics and Space Administration
NAVGEM: Navy Global Environmental Model
NCAR: National Center for Atmospheric Research
NCEP: National Centers for Environmental Prediction
NEIS: NOAA Earth Information System
NEMS: NOAA Environmental Modeling System
NEPTUNE: Navy Environmental Prediction System Utilizing the NUMA Core
NHC: National Hurricane Center
NIM: Non-hydrostatic flow-following finite volume Icosahedral Model
NMMB: Non-hydrostatic Multi-scale Model on B-grid
NMME: National Multi-Model Ensemble
NOAA: National Oceanic and Atmospheric Administration
NPS: Naval Postgraduate School
NRL: Navy Research Laboratory
NUMA: Non-hydrostatic Unified Model for the Atmosphere
NUOPC: National Unified Operational Prediction Capability
NWP: Numerical Weather Prediction
NWS: National Weather Service
OAR: Office of Oceanic and Atmospheric Research
OCIO: Office of the Chief Information Officer
OPC: Ocean Prediction Center
ORNL: Oak Ridge National Laboratory
OWAQ: Office of Weather and Air Quality
PM: Project Manager
PSD: Physical Sciences Division
RMS: Root-Mean-Square

SHUM: Stochastically perturbed boundary-layer HUMidity
SKEB: Stochastic Kinetic Energy Backscatter
SPC: Storm Prediction Center
SPPT: Stochastically Perturbed Physical Tendency
SSISL: Spectral, semi-implicit, semi-Lagrangian
TCVitals: Tropical Cyclone Vital statistics
TACC: Texas Advanced Computing Center
UCACN: UCAR Community Advisory Committee to NCEP
UCAR: University Corporation for Atmospheric Research
UKMO: UK Met Office
VSDB: Verification Statistics Data Base
WPC: Weather Prediction Center
WRF: Weather Research and Forecasting model

Appendix C: EOB Charter

CHARTER
for the
EXECUTIVE OVERSIGHT BOARD
of the
HIGH IMPACT WEATHER PREDICTION PROJECT (HIWPP)

A. Purpose

WHEREAS, authority is granted for this charter under the provisions of the following statutes:

- The National Oceanic and Atmospheric Administration (NOAA) enters into this agreement pursuant to its authority under 15 U.S.C. § 313 and 49 U.S.C. § 44720.
- The Department of the Navy enters into this agreement pursuant to its authority under 10 U.S.C. § 113 and § 5013.

The Parties enter into this charter to establish an Executive Oversight Board (EOB) to oversee activities of the HIWPP.

B. Background

Recent high-impact storms, such as Superstorm Sandy, have shown the impact that these storms can have on lives, property, and economic activity in the U.S. Adequate preparation is dependent on accurate and timely forecasts of these events. While forecasts of Sandy out to several days were very accurate, longer forecasts had more uncertainty and left cities and their residents with less time to prepare.

Congressional interest in the impact of these storms led to the authorization of supplemental funding to address this issue. Specifically, the Congressional language from the supplemental funding documentation stated:

NOAA and its partners will develop and evaluate next generation global atmospheric and oceanic modeling systems to improve the prediction of high-impact weather events, such as hurricanes. Improvements are expected to include advanced data assimilation techniques to utilize observations, more sophisticated representations of atmospheric and oceanic processes, and greater spatial detail in these models. Additionally in terms of next generation global atmospheric and oceanic models, these funds will be used to adapt a new generation of assimilation and forecast models for use in US operational prediction under the auspices of the inter-agency Earth System Prediction Capability. These new models are non-hydrostatic and offer much improved prediction of severe weather such as hurricanes and tornado outbreaks. In addition, the new generation of models will offer, for the first time, skillful extended weather prediction for the period from about two weeks out to several months.

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In line with the Congressional direction, the HIWPP was established to contribute toward the development of the next generation operational modeling system and extend the skillful forecast period of the current high-impact weather prediction system, as well as provide preliminary information on the possibility of high-impact weather predictions out to several months.

The purpose of this charter is to facilitate cooperation between participants in the HIWPP. This charter establishes the underlying basis for collaboration, goals, membership, roles and responsibilities, as well as decision-making oversight for the HIWPP. This includes establishment of an EOB as well as the assignment of a supporting HIWPP Project Manager and an Executive Secretariat/Business Manager.

C. HIWPP Objectives

The HIWPP overarching objectives are to provide rapid real-time research implementation of high-resolution hydrostatic and non-hydrostatic global models to improve high-impact weather forecasting across spatial scales from 3 – 35 km, with an emphasis on forecasts out to 16 days. Additional efforts will be made to prepare these global models for potential use in longer-range forecasts to several months. The project will incorporate flexibility to add or subtract models or model components, and will coordinate with existing operational capabilities and plans to enable common outputs and model output inter-comparisons. This project supports a long-range vision to accelerate development of a global non-hydrostatic weather prediction system capable of running at ~3 km resolution by the end of this decade. This system will provide an alternative to the non-hydrostatic version of NCEP's global spectral model. The outcome will be used by the NOAA National Weather Service (NWS) and the Navy as information regarding possible future changes to current operational modeling systems. The HIWPP objectives also support the broader goals of both Navy and NOAA within the Earth System Prediction System program that includes work on a national approach to an earth system numerical prediction capability.

D. Membership in the HIWPP EOB

The HIWPP EOB will routinely assess and evaluate the developmental activities of the HIWPP as well as the performance of the HIWPP Project and Business Managers.

EOB Chair: Director, NOAA Office of Weather and Air Quality

Members:

a. NOAA

Director, Earth System Research Laboratory
Director, Atlantic Oceanographic & Meteorological Laboratory
Director, National Centers for Environmental Prediction
Director, National Centers for Environmental Prediction Environmental Modeling Center
Director, National Weather Service Office of Science and

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Technology
Director, Geophysical Fluid Dynamics Laboratory
Director, Earth System Research Laboratory Global Systems Division
Director, Earth System Research Laboratory Physical Sciences Division

b. U.S. Navy
Superintendent, Naval Research Laboratory, Monterey

Each EOB Member will be a federal employee and will represent his or her agency/office's programmatic interests while serving on the EOB.

E. Roles and Responsibilities

1. EOB

The EOB provides oversight and guidance to the HIWPP Project Manager in support of project activities.

The EOB has the ability to self-approve this charter through a unanimous membership vote.

Due to the short-term nature of the funding for the HIWPP (Federal funding must be obligated/expended by the end of the 2014 fiscal year), the project schedule is compressed and the EOB will be expected to meet monthly, or as needed, to review HIWPP progress and provide direction to the Project Manager as appropriate. Attendance by a majority of the EOB Members (or their alternates) and the EOB Chair (or Chair's designate) will constitute a quorum needed for decisional briefings. Video teleconference and teleconference capabilities are routinely available, and participation via these technologies constitutes full attendance.

The EOB Members, with the support of their respective staffs and the HIWPP Project Manager and Executive Secretariat/Business Manager, will collect and analyze information to support its recommendations and its oversight responsibilities. Topics brought to the EOB for consideration must be sponsored by an EOB Member, the EOB Chair, the HIWPP Project Manager, or the HIWPP Business Manager. Most decisions will be accomplished informally through informed consensus. The Chair will strive for consensus on every issue. Whether or not there is consensus, the Chair will submit each decisional issue to a vote of the EOB Members. The EOB Chair and each EOB Member will have one vote toward decision matters being considered by the Board. Decisions (other than Charter approval/amendments which require a unanimous vote by EOB Members) will be based on a minimum two-thirds majority vote of the EOB Chair/Members. All EOB decisions will only be made after relevant discussion and deliberation among the EOB Members and the Chair. EOB Members may also move for a formal roll call vote on any decisional item for the record.

The EOB guidance is limited to policy and direction for the project. The EOB will provide this instruction to the Project Manager who holds the responsibility for planning and leading project execution and milestone delivery. The EOB's guidance will include decisions regarding the general planned distribution of funds across NOAA, but details of those fund distributions will lie within the purview of the Project Manager within the guidelines described below.

The EOB will establish thresholds whereby the Project Manager must report changes to the project or request EOB approval to make adjustments. These thresholds will typically be at a high level including:

- changes to overall funds distributions to designated agency financial management offices, (e.g., Financial Management Centers for NOAA),
- impacts to the critical path that result in slips in schedule to one of the project's critical milestones or overall project completion delays of more than 30 days,
- project issues/conflicts raised by an EOB Member for resolution,
- the change in the participation status of the Project Manager or the Business Manager, or
- impacts to key project milestones due to an insurmountable technical, administrative, funding, or management barriers.

The EOB reserves the right to replace the individuals assigned to both the HIWPP Project Manager and Executive Secretariat/Business Manager positions if the Board deems the associated position performance to be substandard. In the event of a replacement action, appropriate NOAA Work Force Management and acquisition protocols must be followed.

2. Project Manager

The Project Manager is directly responsible to the EOB for overall project management, as well as project planning, execution, and milestone delivery. The Project Manager will develop the HIWPP project plan, including overall project methodology, schedules, milestones, performance measures, scope and budget and will maintain the baseline plan and changes to that baseline.

The Project Manager reports to the EOB on a periodic basis as determined by the EOB.

Specific Project Manager responsibilities include the overall direction of the project, development of plans, distribution of funding, tracking progress against project objectives, reporting progress, identifying project deficiencies, and optimizing how project objectives are met (within the previously stated EOB threshold reporting guidance). In performance of these responsibilities, the Project Manager has the discretion to adjust project schedules, specific aspects of the work breakdown structure and individual tasks, the priority of individual project tasks, and how coordination occurs amongst project team members.

The Project Manager has final approval authority for actions within the guiding limitations provided by the EOB.

The Project Manager will be either a Contractor or a NOAA Federal employee from one of participating NOAA offices and will be approved by the EOB.

3. Executive Secretariat/Business Manager

The Executive Secretariat/Business Manager directly supports the EOB Members in tracking and coordinating HIWPP activities. This will include close coordination with the HIWPP Project Manager in coordinating delivery of project tracking documentation, updates, and any responses to EOB queries. The Executive Secretariat/Business Manager provides budget management oversight for the project in support of the EOB. The Executive Secretariat/Business Manager also supports the EOB Chair in answering internal/external project data calls or inquiries and assists the Project Manager in the scheduling and conduct of EOB monthly meetings (and other emerging meeting requirements as needed).

The Executive Secretariat/Business Manager is not authorized to approve actions delegated to the Project Manager unless the Project Manager provides written instructions providing that delegation.

The Executive Secretariat/Business Manager may be either a Contractor or a Federal employee. Assignment to this position will be made by the NOAA Office of Weather and Air Quality and will be approved by the EOB.

4. Supporting Administrative Funding

The Project Manager will be located at ESRL in Boulder, CO. The EOB Executive Secretariat/Business Manager will be located at NOAA Headquarters in Silver Spring, MD. Office space, support staff, internet/ IT services and other administrative functions for these positions will be provided solely by NOAA.

F. Termination Date

This Charter may be amended by unanimous written agreement of all EOB Members. This Charter will remain in effect until all designated HIWPP funding has been expended and EOB Members unanimously agree that oversight of project activities is no longer required. Any Member may withdraw from this Agreement with 90 days written notice provided to the other Members.

G. General Provisions

This Charter is neither a fiscal nor a funds obligation document. Nothing in this Agreement authorizes or is intended to obligate the parties to exchange, or reimburse funds, services, or supplies, or transfer or receive anything of value.

H. Signatures

DATE: 11/25/14
Director, Office of Weather and Air Quality, NOAA/OAR

DATE: 25 Nov 14
Director, National Weather Service Office of Science and Technology, NOAA/NWS

DATE: 11/18/14
Director, Earth System Research Laboratory, NOAA/OAR

DATE: 12/8/2014
Director, Geophysical Fluid Dynamics Laboratory, NOAA/OAR

DATE: 12/4/14
Director, Atlantic Oceanographic and Meteorological Laboratory, NOAA/OAR

DATE: 11/18/14
Director, Earth System Research Laboratory Global Systems Division, NOAA/OAR

DATE: 11/25/14
Director, National Centers for Environmental Prediction, NOAA/NWS

DATE: 11/17/14
Director, Earth System Research Laboratory Physical Sciences Division, NOAA/OAR

DATE: 11/25/14
Director, National Centers for Environmental Prediction Environmental Modeling Center, NOAA/NWS

DATE: 12/15/14
Superintendent, Naval Research Laboratory, Monterey, US Navy

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Appendix D: Draft Data Use Policy

HIWPP Data Use Policy

Statement of Intent and Context:
[This section is internal to the project.]

This HIWPP Data Use Policy and associated process, addresses what, for historical reasons, have been referred to as the "HIWPP Trusted Partner Initiative" and now is being referred to as the HIWPP Open Data Initiative. First it should be noted that this policy takes into consideration a large number of conversations and suggestions that have occurred over an extended period, spanning the project and beyond, and it attempts to balance what is often conflicting guidance and concerns. It should also be noted that the Initiative constitutes a significant step forward in the direction of what the AMS community is calling "Real Time Research."

The policy is guided to the extent possible by two principles: 1) to have an open process that allows interested parties (representing the public, private and academic sectors) to access HIWPP data and to engage in the research process; and 2) to keep it as simple and streamlined as possible. The goal for the HIWPP Open Data Initiative is to have model forecasts viewed by additional users with diverse backgrounds, interests, and priorities, and to glean feedback from these users.

Outreach and Advertisement:
We intend to provide information about this opportunity through the HIWPP web site (http://hiwpp.noaa.gov/), through Unidata, through the AMS Forecast Improvement Group (FIG) and by word of mouth. We consider this process to be dynamic, and depending upon the initial response and ongoing need, we can consider other avenues for outreach.

Process:
Parties interested in accessing HIWPP data will be directed to a web page that will be accessible from the HIWPP web site. (Note, this page will not go live before the HIWPP team, our Executive Oversight Board (EOB), and other relevant parties in NOAA have vetted the process and the language). For a copy of the proposed text that will appear on the web-based registration page, see below.

In summary: the web page will describe that the HIWPP data (model output) are experimental, subject to change, and are not guaranteed to exist beyond the end of the project. *It will also ask people to provide feedback to the project*. To gain access to the data, users will need to check a box acknowledging that they have read and understood the policy and accept the terms, and they will be required to provide their email address. They will also need to indicate if they are seeking access to real-time numerical data, visualized data via NEIS, or both. A confirmation email will be sent immediately, followed by contact within 5 business days with additional information on how to gain access and how to provide feedback. Anyone who registers will be listed on a public web page of data users.

If they have chosen to access the NEIS visualization tool, instructions will include a link where they can download the NEIS client software. In order to protect continued future government access to NEIS technology, NOAA has applied for a patent for NEIS. Users will be required to obtain a non-exclusive, no-cost license as part of this procedure.

As a part of this HIWPP Open Data Initiative, we will conduct regular virtual meetings, probably teleconference calls, with the frequency based on feedback from the community of users. The first virtual meeting will be conducted within the first 3 months following the start of the service. We will convene at least one "HIWPP Open Data Workshop" to engage interactively with interested parties.

Another related web-page to be developed will provide a high-level description of the various means by which people can access the data. As noted in the project plan, several modes of access will be made available, including various means to retrieve the numerical data (such as http or THREDDS) as well as tools to visually interact with the data (NEIS). Disclaimers will be provided within NEIS and on HIWPP data access pages as is practicable.

Finally, a web-based method to collect, track and store feedback from HIWPP Open Data Initiative participants will be developed before this program goes live.

Our goal is to have the HIWPP Open Data Initiative live by early January 2015, commensurate with the HIWPP Real Time Research Runs with the hydrostatic models. The technology and methods for registration and access will be tested with a group of Beta users in the October-December timeframe of 2014.

Risk Mitigation:
[This section is internal to the project.]

The GSD and ESRL technical staff continues to evaluate the potential impact on services to external users for data distribution and visualization tools if response to this initiative is greater than planned. Potential impact on other Boulder infrastructure that may arise from distribution of high resolution data to external users has also been considered, and mitigation strategies have been planned. These include:

- Accepting reduced performance for the services to external users, such as slower response times within NEIS
- Limiting the bandwidth available to external users so that bandwidth to internal NOAA users is not impacted
- Reducing the set of numerical or visual products made available
- Providing sites for mirroring of data, such as Unidata

Until the actual load is determined and the impacts are understood and quantified, it remains to be determined which of these strategies should be adopted.

The Policy: Draft Text for Web Registration page:

HIWPP Data Usage Policy

Introduction

The HIWPP Open Data Initiative goals are to improve the US's medium-range global weather forecasts *<link to page describing HIWPP's scientific goals>*. An important part of this process is to engage with the public, private and academic sectors in the development of new and improved global modeling systems, some experimental.

For some time, the weather enterprise has sought to better engage in the development of weather models. For a good and particularly relevant example of this kind of ongoing effort, see the AMS Forecast Improvement Group's (FIG) Summary of Recommendations (especially relevant for HIWPP are recommendations 1, 2, 4, and 7). To this end, beginning in January of 2015 and lasting for at least 1 year, HIWPP will provide access *<link to page describing access methods>* to the experimental global model output from HIWPP.

Purpose

The intent of our HIWPP Open Data Initiative first is to provide a mechanism for interaction between public, private, and academic sectors with our project as we develop and explore models that are relatively mature in their developmental life cycle. This provides a benefit to the weather community by giving timely access to high quality, experimental model output, at higher spatial and temporal resolution, and to new tools to analyze, evaluate and visualize these data.

Second, the community can help us to improve these models. As informed users of model data, this user community can greatly expand the application of these data over a wider array of high-impact weather phenomena and a broader range of the globe, leading to a more robust and effective product development cycle. Feedback on the model forecasts, the post-processed data, and the data delivery and visualization tools will be used to improve models and products.

Users need to understand that HIWPP data is experimental and will not necessarily be implemented operationally, pending many considerations.

Below, we identify some basic terms and conditions for you to consider before using these data, and we ask you to acknowledge these terms and provide us with an email address. We will then contact you within 5 business days to provide you with instructions on how to gain access to the data and how to provide feedback. At that time you will also be added to the "Participants Page," and you become a *HIWPP Data User.* As you look at and use these data and tools, we request that you engage constructively with the HIWPP team and provide feedback. Several avenues will be provided to engage, including a web-based submission process, periodic teleconference virtual meetings, and a workshop.

Initial Timeline

- December 2014 – beta testing of real-time distribution of infrastructure
- By January 2015 – open access to available HIWPP data feeds and NEIS
- February – March 2015 – first virtual meeting of HIWPP data users
- June 2015 – HIWPP Open Data Workshop
- January 2016 – HIWPP Open Data Initiative concludes (upon review)

HIWPP Data Usage Policy (continued)

Data Use

First and foremost, these are not the official products and forecasts of NOAA – those products and services are issued by the National Weather Service, and can be found at:

- Official Forecasts (NWS): http://www.weather.gov
- Official Model Products (NWS/NCEP): http://mag.ncep.noaa.gov

These model outputs and forecasts are **EXPERIMENTAL**:

- They are provided without warranty of any kind and you use them at your own risk
- The data and data streams are subject to change at any time
- While the data will likely be stored long-term for R&D, in most cases, the real-time data streams are expected to terminate at the conclusion of this project
- Data availability for HIWPP will not be as maintained at as high a level as that for NWS operational models. Some outages will likely occur due to research computer outages, planned maintenance downtimes, or other reasons.

Please note that available bandwidth for the distribution of real-time data is a shared resource, and performance for individual users cannot be guaranteed. We ask that all users only download data that they will be actively reviewing.

Finally, we ask that you credit the source of data in your usage.

How Do I Sign Up?

Please acknowledge that you've read, understood, and agree to the principles outlined herein, and provide us with your email address. You will receive an email within 5 business days with further information and instructions.

☐ I acknowledge that I have read and understand these terms and conditions and agree to them.

your.email@goes.here

More Information

Watch this web page for further developments.

Do you still have questions? Email us at <'HIWPP_Users@noaa.gov' *(or similar)*>

Additional (Supporting) Web Pages

To be developed: supporting pages that will be linked from the Data Usage page above will include:

1. Statement of HIWPP's scientific goals. Very roughly:
   a. To improve hydrostatic models (high resolution)
   b. To improve post processing and ensembles
   c. To evaluate candidate non-hydrostatic dynamical cores, physics and 4DEnVar (with a note that at this time non-hydrostatic model output is not expected to be delivered in real-time)
   d. To develop and test new tools to deliver, evaluate and visualize model data
2. High-level description of various means to access HIWPP data and data flow diagram
3. List of participating users who have "registered"
4. A web-based vehicle for submitting, tracking and documenting comments and feedback

Test and Distribution Plan

Alpha testing:

In order to confirm the software and infrastructure developed to support the Open Data Initiative operates correctly and performs as expected, initial testing will be performed with a select set of non-commercial testers. Current possible testers include:

- CIRA in Fort Collins, testing both NEIS and real-time data distribution
- Satellite liaison (NESDIS-funded Cooperative Institutes) users
- NWS training personnel

It is anticipated that this limited group of users would primarily test functionality of getting access, installation of NEIS client, performance of NEIS with a limited number of users, and distribution of real-time data.

Beta testing:

The second level of testing will be available to all interested parties, but the total number of testers will be limited. This testing will continue to test all functionality as in Alpha testing, but will additionally test infrastructure under a heavier, but carefully managed, load.

In order to provide for equitable access, an announcement will be made on the HIWPP website that will provide information on how to sign up as Beta a tester. This will be set up on a first-come-first-served basis such that when the pre-defined number of Beta testers has been filled, no further applications will be accepted.

Email list for interested parties:

A number of individuals and companies have expressed an early interest in HIWPP model data and/or NEIS. In order to provide information to those parties and still provide equitable access to all, a notice will be placed on the HIWPP website that will allow interested parties to subscribe to an email list for further information. The email list will be used to provide notification of any new opportunities that become available. The website address to subscribe to the email list will be provided to those who have already indicated an interest in HIWPP data.

Information through AMS Forecast Improvement Group (FIG)

A webinar in January 2014 was presented to AMS FIG providing a high-level overview of the HIWPP project and plans to make data available to interested parties in a real-time research mode. A second webinar will be made available in

November 2014 to provide updated information about the project and how interested parties may participate.

Schedule:

The following schedule for testing and live data is planned:

Early October 2014	Email list for interested parties made available and advertised on HIWPP web page
Early November 2014	Alpha testing begins and continues for 3 weeks
Early December 2014	Beta testing begins and continues for 2 weeks
January 1, 2015	The full system goes live and continues for 1 year

This schedule is contingent on all hardware and infrastructure becoming available as planned.